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(54) **Title:** METHOD AND APPARATUS FOR RECOVERING CT DATA OF LOW CREDIBILITY

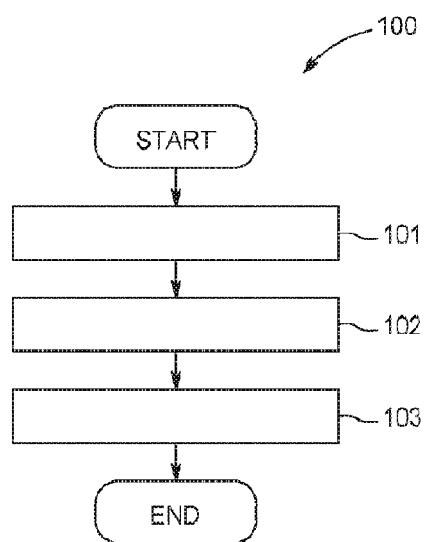


FIG. 1

(57) **Abstract:** The present invention relates to a method and apparatus for recovering CT data of low credibility. The method comprises: acquiring a low credibility region at a projection space; performing a forward projection on all or some of pixel points on a reconstructed image to obtain projection tracks; and recovering an overlapped region on which the projection tracks pass through the low credibility region.

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METHOD AND APPARATUS FOR RECOVERING CT DATA OF LOW CREDIBILITY

FIELD

[0001] The present invention relates to the technical field of Computed Tomography (CT), particularly to a method and apparatus for recovering CT data of low credibility.

BACKGROUND

[0002] In a CT device, a detector may collect X-rays that pass through an object to be scanned and convert those X-rays into electric signals. Those electric signals are recorded and then constitute CT original data, which is also called CT projection data. After reconstructing the CT projection data by a corresponding reconstruction algorithm, a CT image may be obtained.

[0003] Because of the reasons that the performance of some channels on the detector is degraded, the object to be scanned contains metal and the like, the CT projection data would include data of low credibility. Artifacts would appear on the CT image obtained by reconstruction with those data.

[0004] The existing method for recovering data of low credibility in the CT projection data usually performs data recovery on one or more of three dimensions, i.e., view, a number of channels of the detector along the X-direction and a number of rows of the detector along the Z-direction generated by the projection data based on the three dimensions. However, the accuracy of the data recovered by the existing method is not high enough, and the recovering effect is not good for the region where a density difference of objects is larger on the CT image.

[0005] Therefore, there is a need to provide a method and apparatus for recovering CT data of low credibility, which is capable of recovering CT data more accurately.

SUMMARY

[0006] One embodiment of the present invention provides a method for recovering CT data of low credibility, comprising: acquiring a low credibility region at a projection space;

performing a forward projection on all or some of pixel points on a reconstructed image to obtain projection tracks; and recovering an overlapped region on which the projection tracks pass through the low credibility region.

[0007] Another embodiment of the present invention provides an apparatus for recovering CT data of low credibility, comprising: a low credibility region acquisition module for acquiring a low credibility region at a projection space; a forward projection module for performing a forward projection on all or some of pixel points on a reconstructed image to obtain projection tracks; and an overlapped region recovery module for recovering an overlapped region on which the projection tracks pass through the low credibility region.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present invention can be better understood in light of the following description of embodiments of the present invention with reference to the accompanying drawings, in which:

[0009] Fig. 1 is a schematic flow chart illustrating one embodiment of a method for recovering CT data of low credibility of the present invention;

[0010] Fig. 2 is a schematic flow chart illustrating one embodiment of acquiring a low credibility region at a projection space during the process of recovering CT data of low credibility of the present invention;

[0011] Fig. 3 is a schematic flow chart illustrating one embodiment of acquiring a low credibility region at a projection space during the process of recovering CT data of low credibility of the present invention;

[0012] Fig. 4 is a schematic flow chart illustrating one embodiment of recovering an overlapped region where the projection tracks pass through the low credibility region during the process of recovering CT data of low credibility of the present invention;

[0013] Fig. 5 is a schematic diagram illustrating that a projection track passes through the low credibility region;

[0014] Fig. 6 is a schematic diagram illustrating a credible region on the projection track as shown in Fig. 5;

[0015] Fig. 7 is a schematic diagram illustrating interpolation on the overlapped region on the projection track;

[0016] Fig. 8A illustrates a reconstructed image obtained by reconstruction with the

projection data containing data of low credibility;

[0017] Fig. 8B illustrates a reconstructed image obtained by reconstruction after recovering the data of low credibility using the prior art;

[0018] Fig. 8C illustrates a reconstructed image obtained by reconstruction after recovering the data of low credibility using the technical solution of the present invention;

[0019] Fig. 9 is a schematic block diagram illustrating one embodiment of an apparatus for recovering CT data of low credibility of the present invention.

DETAILED DESCRIPTION

[0020] Hereafter, a detailed description will be given for preferred embodiments of the present disclosure. It should be pointed out that in the detailed description of the embodiments, for simplicity and conciseness, it is impossible for the Description to describe all the features of the practical embodiments in details. It should be understood that in the process of a practical implementation of any embodiment, just as in the process of an engineering project or a designing project, in order to achieve a specific goal of the developer and in order to satisfy some system-related or business-related constraints, a variety of decisions will usually be made, which will also be varied from one embodiment to another. In addition, it can also be understood that although the effort made in such developing process may be complex and time-consuming, some variations such as design, manufacture and production on the basis of the technical contents disclosed in the disclosure are just customary technical means in the art for those of ordinary skilled in the art relating to the contents disclosed in the present invention, which should not be regarded as insufficient disclosure of the present invention.

[0021] Unless defined otherwise, all the technical or scientific terms used in the Claims and the Description should have the same meanings as commonly understood by one of ordinary skilled in the art to which the present disclosure belongs. The terms "first", "second" and the like in the Description and the Claims of the present utility model do not mean any sequential order, number or importance, but are only used for distinguishing different components. The terms "a", "an" and the like do not denote a limitation of quantity, but denote the existence of at least one. The terms "comprises", "comprising", "includes", "including" and the like mean that the element or object in front of the "comprises", "comprising", "includes" and "including" covers the elements or objects and their

equivalents illustrated following the "comprises", "comprising", "includes" and "including", but do not exclude other elements or objects. The term "coupled" or "connected" or the like is not limited to being connected physically or mechanically, nor limited to being connected directly or indirectly.

[0022] In order to make the purpose, the technical solutions and the advantages of the invention more apparent, the technical solutions of the present invention will be set forth clearly and fully in the following by combining with specific embodiments of the invention and the corresponding accompanying drawings. Obviously, the described embodiments are merely part— not all— of the embodiments in the present invention. In view of the embodiments in the present invention, other embodiments made by one of ordinary skilled in the art without inventive work all fall within the scope of protection of the invention.

[0023] In accordance with the embodiments of the present invention, a method for recovering CT data of low credibility is provided.

[0024] Referring to Fig. 1, which is a schematic flow chart illustrating one embodiment of a method 100 for recovering CT data of low credibility of the present invention.

[0025] As shown in Fig. 1, in Step 101, a low credibility region at a projection space is acquired.

[0026] The low credibility region may be a low credibility region on which a hardware defect is reflected onto the projection space, and may also be a low credibility region on which a metal on the scanned object is reflected onto the projection space. For example, the low credibility region may be a region on the projection space to which a metal region on the initial reconstructed image corresponds, and may also be a region on the projection space to which some known detector channels of low performance correspond, and may further be a region reflected onto the projection space due to the reasons such as tube spit.

[0027] For the situation of known detector channels of low performance, the corresponding detector channel may be directly selected on the projection space, and a region composed of all data corresponding to the channel may be regarded as the low credibility region. For the situation of tube spit, a region composed of all data for the view may be regarded as the low credibility region.

[0028] In one embodiment of the present invention, referring to Fig. 2, Step 101 may comprise the following Sub-Steps 201 to 202, i.e., a low credibility region at the projection space may be acquired by the following Sub-Steps 201 to 202.

[0029] In Sub-Step 201, an objective region is selected on the reconstructed image.

[0030] The reconstructed image may be obtained by a method of reconstructing the CT image with projection data containing data of low credibility. On the reconstructed image, the objective region may be selected. The objective region may be a region where an artifact resides, and may also be a region of a lower credibility considered by the user.

[0031] In Sub-Step 202, a forward projection is performed on the objective region to obtain the low credibility region.

[0032] A forward projection may be performed on the objective region selected by Sub-Step 201, and a region of the objective region at the projection space, i.e., low credibility region, may just be obtained.

[0033] In another embodiment of the present invention, referring to Fig. 3, Step 101 may also comprise the following Sub-Steps 301 to 302, i.e., a low credibility region at the projection space may be acquired by the following Sub-Steps 301 to 302.

[0034] In Sub-Step 301, artifact information is acquired on the reconstructed image.

[0035] For some artifacts of specific styles, for example, steak artifact, ring artifact, band artifact and the like, information such as their shapes, positions, sizes and the like may be recognized from the reconstructed image.

[0036] In Sub-Step 302, the low credibility region is computed in accordance with the artifact information.

[0037] For example, information such as the view, the number of channels of the detector along the X-direction, the number of rows of the detector along the Z-direction and the like may be computed from the direction of the steak artifact and the distance from the steak artifact to the rotation center, thereby determining the region of the steak artifact in the projection space. For another example, the view, the number of channels and the number of rows of the ring artifact or the band artifact may be computed from the radius and the circumference coverage range of the ring artifact or the band artifact, thereby determining the region of the ring artifact or the band artifact in the projection space.

[0038] In Step 102, a forward projection is performed on all or some of pixel points on a reconstructed image to obtain projection tracks.

[0039] In one embodiment of the present invention, a forward projection is performed on pixel points in a region on the reconstructed image where objects of larger densities (for example, metal, skeleton, etc.,) reside to obtain projection tracks of those pixel points.

[0040] In another embodiment of the present invention, a forward projection is performed on pixel points in a region on the reconstructed image where a density difference of objects is larger (for example, a region where substance of high density is adjacent to substance of low density) to obtain projection tracks of those pixel points.

[0041] Reconstructing an image as stated herein may be obtaining a reconstructed image by a method of CT image reconstruction with projection data containing data of low credibility.

[0042] In Step 103, an overlapped region on which the projection tracks pass through the low credibility region is recovered.

[0043] The part that the projection tracks obtained by Step 102 pass through the low credibility region obtained by Step 101 is just the portion that needs to be recovered in Step 103. In one embodiment of the present invention, with reference to Fig. 4, Step 103 may include the following Sub-steps 401 to 403.

[0044] In Sub-Step 401, an overlapped region is selected on the projection tracks.

[0045] Referring to Fig. 5, in Fig. 5, the thinner curve is a projection track of one pixel point obtained by Step 102, and the thicker curve band represents a low credibility region obtained by Step 101. And the part on the thinner curve that passes through the thicker curve band is just the overlapped region.

[0046] In Sub-Step 402, an interpolation is performed on the overlapped region in accordance with the trends of the projection tracks.

[0047] In the projection space of some CT machines, the projection tracks are sinusoidal curves, therefore in one embodiment of the present invention, an interpolation recovery may be performed for the overlapped region on the projection tracks in accordance with the trends of the sinusoidal curves. As shown in Fig. 6, the part on which the projection track does not pass through the low credibility region may be regarded as a credible region. Therefore, an extrapolation may be performed on the overlapped region using the data within the credible region and in accordance with a sinusoidal change pattern of the projection track, so as to obtain the values of the projection track positioned within the overlapped region. Fig. 7 shows a track of a projection track within the overlapped region, the projection track being obtained by performing an interpolation on the overlapped region. Thus, a complete projection track may be obtained.

[0048] In the projection space of other CT machines, the projection tracks may be

sinusoidal-like curves or other curves of any higher powers, therefore in another embodiment of the present invention, an interpolation recovery may be performed for the overlapped region on the projection tracks in accordance with the trends and the change patterns of the sinusoidal-like curves or the curves of higher powers.

[0049] In Sub-Step 403, the projection tracks after being interpolated are weighted and summed.

[0050] In one embodiment of the present invention, when a plurality of projection tracks pass the same low credibility region, the complete projection tracks obtained after interpolation may be weighted and summed. The weights of the projection tracks may be equal. The projection tracks of greater strength may be assigned greater weights as well.

[0051] In one embodiment of the present invention, the CT data after being recovered may further be merged with the CT data before being recovered. Such merging process may be a weighted superimposing process, for instance, the projection data after being recovered may be trusted entirely while the data before being recovered may not be trusted at all. The data after being recovered may also be trusted partly, in this way, the data before being recovered and the data after being recovered may be assigned with some weights respectively and the two may be weighted superimposed with each other. The data as stated herein may be projection data, and may also be data of the reconstructed image, i.e., this merging may be performed at a projection space, and may also be performed at an image space.

[0052] So far, a method for recovering CT data of low credibility according to the embodiments of the present invention has been described. In comparison with Fig. 8A, Fig. 8B and Fig. 8C, it can be seen that the method of the present invention is capable of recovering CT projection data more accurately while avoiding new artifacts due to inaccurate interpolation. Furthermore, the method of the present invention can also reduce requirements for hardware on a CT image chain, thereby reducing the cost.

[0053] Similar to the method, the present invention also provides the corresponding apparatus.

[0054] Fig. 9 is a schematic block diagram illustrating one embodiment of an apparatus for recovering CT data of low credibility of the present invention.

[0055] As shown in Fig. 9, an apparatus 900 may comprise: a low credibility region acquisition module 901 for acquiring a low credibility region at a projection space; a forward

projection module 902 for performing a forward projection on all or some of pixel points on a reconstructed image to obtain a projection track; and an overlapped region recovery module 903 for recovering an overlapped region on which the projection tracks pass through the low credibility region.

[0056] In one embodiment of the present invention, the low credibility region acquisition module 901 may further comprise: an objective region selection module for selecting an objective region on the reconstructed image; and an objective region forward projection module for performing a forward projection on the objective region to obtain the low credibility region.

[0057] In another embodiment of the present invention, the low credibility region acquisition module 901 may further comprise: an artifact information acquisition module for acquiring artifact information on the reconstructed image; and a module for computing the low credibility region in accordance with the artifact information.

[0058] In one embodiment of the present invention, the forward projection module 902 may further comprise: a large density region forward projection module for performing a forward projection on pixel points in a region on the reconstructed image where objects of larger densities reside.

[0059] In another embodiment of the present invention, the forward projection module 902 may further comprise: a region of large difference forward projection module for performing a forward projection on pixel points in a region on the reconstructed image where a density difference of objects is larger.

[0060] In one embodiment of the present invention, the overlapped region recovery module 903 may further comprise: an overlapped region selection module for selecting the overlapped region on the projection tracks; an interpolation module for performing an interpolation on the overlapped region in accordance with the trends of the projection tracks; and a weighting and summing module for weighting and summing the projection tracks after being interpolated.

[0061] In one embodiment of the present invention, the interpolation module may further comprise: a sinusoidal trend interpolation module for performing an interpolation on the overlapped region in accordance with a trend of a sinusoidal curve.

[0062] In one embodiment of the present invention, the overlapped region recovery module 903 may further comprise: a data merging module for merging the CT data after

being recovered with the CT data before being recovered.

[0063] So far, an apparatus for recovering CT data of low credibility according to the embodiments of the present invention has been described. In comparison with Fig. 8A, Fig. 8B and Fig. 8C, it can be seen that similar to the above method, the apparatus of the present invention is capable of recovering CT projection data more accurately while avoiding new artifacts due to inaccurate interpolation. Furthermore, the apparatus of the present invention can also reduce requirements for hardware on a CT image chain, thereby reducing the cost.

[0064] The above descriptions are merely embodiments of the invention and are not intended to restrict the scope of the invention. All kinds of variations and modifications could be made to the present invention to those skilled in the art. Any modifications, alternatives and improvements made within the spirit and principles of the present invention shall fall within the scope of the appended claims.

What is claimed is:

1. A method for recovering CT data of low credibility, comprising:
acquiring a low credibility region at a projection space;
performing a forward projection on all or some of pixel points on a reconstructed image to obtain projection tracks; and
recovering an overlapped region on which the projection tracks pass through the low credibility region.
2. The method according to Claim 1, wherein the step of acquiring a low credibility region at a projection space further comprises:
selecting an objective region on the reconstructed image; and
performing a forward projection on the objective region to obtain the low credibility region.
3. The method according to Claim 1, wherein the step of acquiring a low credibility region at a projection space further comprises:
acquiring artifact information on the reconstructed image; and
computing the low credibility region in accordance with the artifact information.
4. The method according to Claim 1, wherein the step of performing a forward projection on all or some of pixel points on a reconstructed image to obtain projection tracks further comprises:
performing a forward projection on pixel points in a region on the reconstructed image where objects of larger densities reside.
5. The method according to Claim 1, wherein the step of performing a forward projection on all or some of pixel points on a reconstructed image to obtain projection tracks further comprises:
performing a forward projection on pixel points in a region on the reconstructed image where a density difference of objects is larger.

6. The method according to Claim 1, wherein the step of recovering an overlapped region on which the projection tracks pass through the low credibility region further comprises:

- selecting the overlapped region on the projection tracks;
- performing an interpolation on the overlapped region in accordance with trends of the projection tracks; and
- weighting and summing the projection tracks after being interpolated.

7. The method according to Claim 6, wherein the step of performing an interpolation on the overlapped region in accordance with trends of the projection tracks further comprises:

- performing an interpolation on the overlapped region in accordance with a trend of a sinusoidal curve.

8. The method according to Claim 6, further comprising:

- merging the CT data after being recovered with the CT data before being recovered.

9. An apparatus for recovering CT data of low credibility, comprising:

- a low credibility region acquisition module for acquiring a low credibility region at a projection space;
- a forward projection module for performing a forward projection on all or some of pixel points on a reconstructed image to obtain projection tracks; and
- an overlapped region recovery module for recovering an overlapped region on which the projection tracks pass through the low credibility region.

10. The apparatus according to Claim 9, wherein the low credibility region acquisition module further comprises:

- an objective region selection module for selecting an objective region on the reconstructed image; and
- an objective region forward projection module for performing a forward projection on the objective region to obtain the low credibility region.

11. The apparatus according to Claim 9, wherein the low credibility region acquisition module further comprises:

an artifact information acquisition module for acquiring artifact information on the reconstructed image; and

a module for computing the low credibility region in accordance with the artifact information.

12. The apparatus according to Claim 9, wherein the forward projection module further comprises:

a large density region forward projection module for performing a forward projection on pixel points in a region on the reconstructed image where objects of larger densities reside.

13. The apparatus according to Claim 9, wherein the forward projection module further comprises:

a region of large difference forward projection module for performing a forward projection on pixel points in a region on the reconstructed image where a density difference of objects is larger.

14. The apparatus according to Claim 9, wherein the overlapped region recovery module further comprises:

an overlapped region selection module for selecting the overlapped region on the projection tracks;

an interpolation module for performing an interpolation on the overlapped region in accordance with trends of the projection tracks; and

a weighting and summing module for weighting and summing the projection tracks after being interpolated.

15. The apparatus according to Claim 14, wherein the interpolation module further comprises:

a sinusoidal trend interpolation module for performing an interpolation on the

overlapped region in accordance with a trend of a sinusoidal curve.

16. The apparatus according to Claim 14, wherein the overlapped region recovery module further comprises:

a data merging module for merging the CT data after being recovered with the CT data before being recovered.

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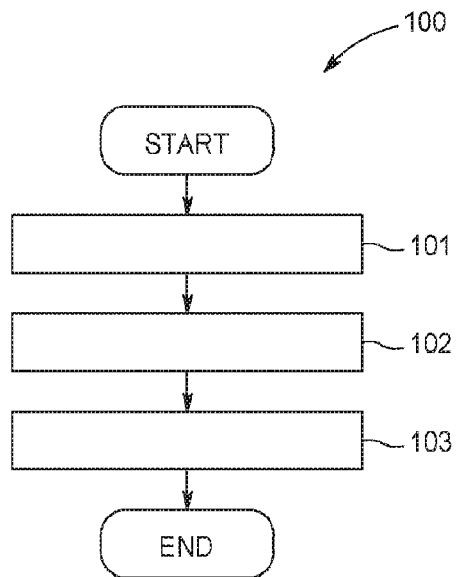


FIG. 1

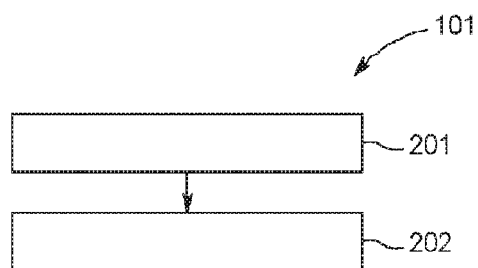


FIG. 2

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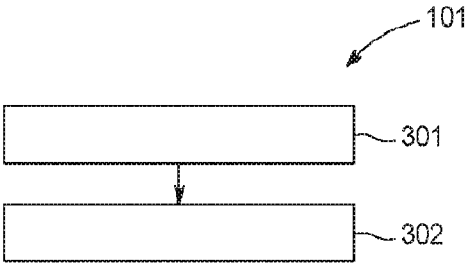


FIG. 3

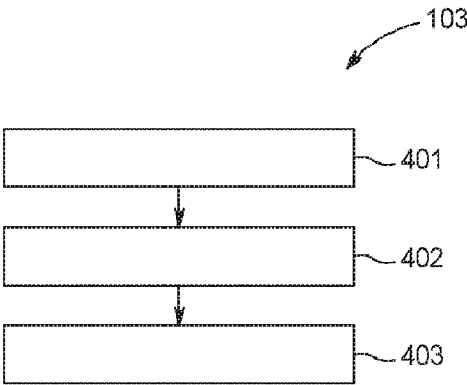


FIG. 4

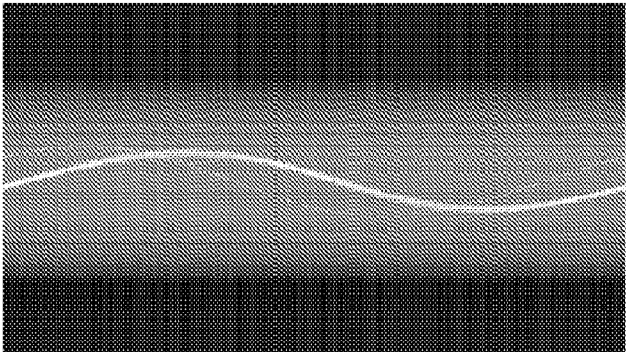


FIG. 5

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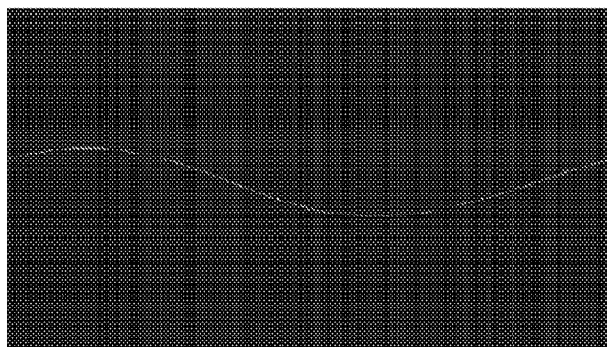


FIG. 6



FIG. 7

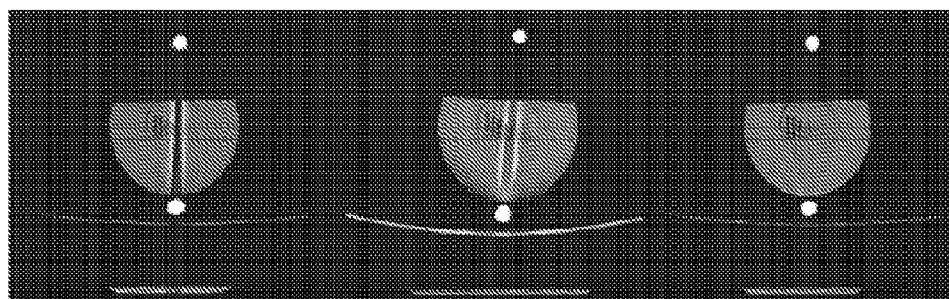


FIG. 8A

FIG. 8B

FIG. 8C

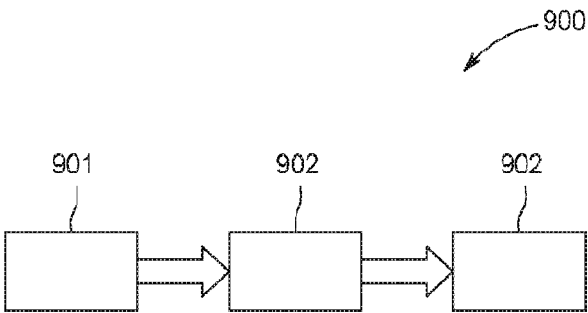


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US16/38462

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61B 6/02; G01T 1/29; G06T 11/00 (2016.01)

CPC - A61B 6/027, 6/5235, 6/5258; G01T 1/2985; G06T 11/005

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)

IPC(8): A61B 6/02; G01T 1/29; G06T 11/00 (2016.01)

CPC: A61B 6/027, 6/5235, 6/5241, 6/5258; G01T 1/2985; G06T 11/005, 2211/40, 2211/424

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)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Google; Google Scholar; EBSCO; KEYWORDS: data recovery CT projection data interpolation estimate pixel points reconstructed image overlapped region projection tracks texture orientation trace trajectory

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2008/0056437 A1 (PACK, J. et al.) March 6, 2008; figures 1-2; paragraphs [0028, 0039-0040, 0043, 0045-0046, 0048]	1-3, 6, 8-11, 14, 16 ----- 4-5, 7, 12-13, 15
Y	US 2012/0155617 A1 (DUTTA, S. et al.) June 21, 2012; paragraphs [0010-0012, 0044]	4-5, 12-13
Y	US 2014/0270448 A1 (UNIVERSITY OF MACAU) September 18, 2014; paragraphs [0075, 0116]	7, 15

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search

23 August 2016 (23.08.2016)

Date of mailing of the international search report

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