(54) Title: SEGMENTATION OF MOVING STRUCTURE IN IMAGE DATA

(57) Abstract: A method includes obtaining projection data from a scan of a moving structure of interest. The method further includes reconstructing the projection data, generating first image data. The method further includes identifying a sub-set of the projection. The method further includes reconstructing the sub-set projection data, generating second image data. The method further includes identifying a region in which the moving structure of interest is located based on the first image data. The method further includes identifying a location of the moving structure of interest in the identified region based on the second image data.

![Diagram of the process flow]

FIG. 9

Declarations under Rule 4.17:
— as to applicant’s entitlement to apply for and be granted a patent (Rule 4.17(iii))
— as to the applicant’s entitlement to claim the priority of the earlier application (Rule 4.17(iv))

Published:
— with international search report (Art. 21(3))
The following generally relates to imaging moving structure and more particular to segmenting moving structure in image data, and is described with particular application to computed tomography (CT). However, the following is also amenable to other imaging modalities such as positron emission tomography (PET), single photon emission tomography (SPECT), magnetic resonance (MR), x-ray tomography, and/or other modalities.

A computed tomography (CT) scanner generally includes an x-ray tube mounted on a rotatable gantry opposite a detector array across an examination region. The rotatable gantry and hence the x-ray tube rotate around the examination region and a subject therein. The x-ray tube emits radiation that traverses the examination region and the subject. The detector array detects radiation that traverses the examination region and generates projection data indicative thereof. A reconstructor reconstructs the projection data, generating volumetric image data indicative of the scanned subject.

However, subject motion during scanning may introduce artifact into the projection data and hence the reconstructed volumetric image data. For example, cardiac motion during a cardiac scan gated at a quiet phase of the cardiac cycle may result in blurring of the coronary vessels. Unfortunately, such motion artifact may make further processing of the coronary vessels, such as automatic and/or manual coronary artery segmentation, difficult, and segmentation of the coronary vessels from CT is used, for example, to facilitate the diagnosis of coronary lesions or, where the segmentation is performed in multiple different cardiac phases, for motion estimation and compensation.

FIGURE 1 shows an example of such blurring. In FIGURE 1, image data 102 from a contrast-enhanced cardiac axial scan is illustrated. A coronary artery 104 of interest moves, with the beating heart, during the scan. As a result, the coronary artery 104 shows up as a blurred arc 106 in the image data 102. The degree of blurring corresponds to the path of the motion and depends on the rotation speed of the rotating gantry and x-ray tube. With the vessel blurred as shown in FIGURE 1, only a rough guess of the location of the vessel can be made. A vessel 108 represents a substantially less blurred vessel. In general, a non-burred vessel would show up a compact bright structure.
Aspects described herein address the above-referenced problems and others. 

The following describes an approach to segment a moving structure from image data. With this approach, a first reconstruction provides lower temporal resolution of the moving structure of interest and surrounding structure. A second reconstruction, performed with a sub-set of the projection data used for the first reconstruction, has higher temporal resolution and thus less motion artifact than the first reconstruction. That is, the blurring in the second reconstruction is more compact because the project data for the second reconstruction covers a shorter time interval and hence there is less motion. The combination of the first and second reconstruction is used to segment the moving structure of interest.

In one aspect, a method includes obtaining projection data from a scan of a moving structure of interest. The method further includes reconstructing the projection data, generating first image data. The method further includes identifying a sub-set of the projection. The method further includes reconstructing the sub-set projection data, generating second image data. The method further includes identifying a region in which the moving structure of interest is located based on the first image data. The method further includes identifying a location of the moving structure of interest in the identified region based on the second image data.

In another aspect, a moving structure of interest segmentor includes a first reconstructor that reconstructs projection data corresponding to a scan of a moving structure, generating first image data. The moving structure of interest segmentor further includes a second reconstructor that reconstructs a sub-set of projection data, generating second image data. The moving structure of interest segmentor further includes a rendering engine that visually displays the first and the second image data. The moving structure of interest segmentor further includes an input device(s) that receives a first input indicative of a region in the first image data in which the moving structure of interest is located and a second indicative of a location within the region at which the moving structure of interest is located. The moving structure of interest segmentor further includes a segmentor that segments the moving structure of interest based on the location.

In another aspect, a computer readable storage medium is encoded with computer readable instructions. The computer readable instructions, when executed by a processor, causes the processor to: reconstruct at least two image data sets from different portions of a same set of projection data, wherein the at least two image data sets have different temporal resolution, locate moving structure of interest based on the at least two
image data sets, and segment the moving structure of interest based on the located moving structure of interest.

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 shows image data from a contrast-enhanced cardiac axial scan in which a coronary vessel of interest is blurred due to cardiac motion.

FIGURE 2 schematically illustrates an example computing system with a moving structure of interest segmentor in connection with an imaging system.

FIGURE 3 schematically illustrates an example of the moving structure of interest segmentor.

FIGURE 4 schematically illustrates a 180 degree scan.

FIGURE 5 schematically illustrates an angular subset of the 180 degree scan of FIGURE 4, centered on the 180 degree scan, identified for a lower motion artifact reconstruction.

FIGURE 6 shows lower motion artifact image data corresponding to the lower motion artifact reconstruction of FIGURE 5.

FIGURE 7 shows an example visualization in which lower temporal resolution and lower motion artifact image data are concurrently displayed.

FIGURE 8 schematically illustrates a less than 90 degree angular subset of a greater than 180 degree scan, not centered on the scan.

FIGURE 9 illustrates a method for segmenting a moving structure of interest in image data.

Initially referring to FIGURE 2, an example imaging system 200, such as a computed tomography (CT) scanner, is schematically illustrated. The imaging system 200 includes a generally stationary gantry 202 and a rotating gantry 204. The rotating gantry 204 is rotatably supported by the stationary gantry 202 and rotates around an examination region 206 about a longitudinal or z-axis.

A radiation source 208, such as an x-ray tube, is rotatably supported by the rotating gantry 204. The radiation source 208 rotates with the rotating gantry 204 and emits radiation that traverses the examination region 206.

A one or two-dimensional radiation sensitive detector array 210 subtends an angular arc opposite the radiation source 208 across the examination region 206. The
detector array 210 includes a plurality of rows of detectors that extend along the z-axis direction. The detector array 210 detects radiation traversing the examination region 206 and generates projection data indicative thereof.

A subject support 212, such as a couch, supports an object or subject in the examination region 206. The support can be before, during and/or after scanning. This includes loading and unloading the subject in the examination region 206.

A computing system serves as an operator console 214 and includes a human readable output device such as a monitor and an input device such as a keyboard, mouse, etc. The console 214 allows an operator to interact with the scanner 200 via a graphical user interface (GUI) and/or otherwise. For instance, the user can select a 180 degree cardiac scan protocol (e.g., in which data is acquired over 180 degrees and includes data corresponding to 180 degrees plus a source fan). The user can also select a scan that is less than 180 degrees and a scan that is greater than 180 degrees.

A reconstructor 216 reconstructs the projection data and generates volumetric data indicative thereof. This includes utilizing a reconstruction algorithm based on the acquisition protocol. For example, a 180 degree reconstruction can be utilized for scans performed with 180 degree acquisition protocol or a protocol with a higher angular range.

A computing system 218 includes at least one microprocessor 220 and a computer readable storage medium ("memory") 222. The memory 222 excludes transitory medium and includes physical memory and/or other non-transitory storage medium. The microprocessor 220 executes at least a moving structure of interest segmentor 224 instruction(s) stored in the memory 222. The microprocessor 220 may also executes a computer readable instruction carried by a carrier wave, a signal or other transitory medium. The computing system 218 can be part of the console 214 and/or separate therefrom (as illustrated in FIGURE 2).

The moving structure of interest segmentor 224 instruction(s) at least includes an instruction(s) for processing at least projection and/or image data of a scanned moving structure of interest. As described in greater detail below, this includes generating at least two sets of image data from the projection data, including a first set of image data with first temporal resolution and first motion artifact and a second set of image data with second temporal resolution and second motion artifact, where the first temporal resolution is lower and the first motion artifacts are greater than the second temporal resolution and the second artifacts respectively, and utilizing one or more of the at least two sets of image data to segment the scanned moving structure of interest.
This approach provides separate sets of image data from a single scan, one that can be used as a guide to a general region in the image data where the scanned moving structure of interest is located (the lower temporal resolution image data) and one to identify the scanned moving structure of interest in the general region (the lower motion artifact image data). The separate sets of image data can be viewed individually or in combination, for example, as separate or combined image data sets. This approach may mitigate guessing a location of the scanned moving structure of interest at a particular time point of interest, for example, due to blurring of the scanned moving structure of interest in the image data, in a configuration in which only a single set of image data is utilized.

In the illustrated embodiment, the memory 222 also includes an evaluation instruction. The evaluation 226 instruction, in one instance, performs a quantitative evaluation of the moving structure of interest based on the segmented moving structure of interest. The evaluation 226 instruction, in another instance, utilizes the segmented moving structure of interest in connection with motion estimation and compensation. In other instances, the evaluation 226 instruction utilizes the segmented moving structure of interest for other processing.

The computing system 218 further includes an output device(s) 228 such as a display monitor, a filer, etc., and an input device(s) 230 such as a mouse, keyboard, etc. The output device(s) 228 can be used to visually display image data such as image data reconstructed at a motion phase of interest and/or at one or more other motion phases. The input device(s) 230, as described in greater detail below, can be used to one or more of select an angular range for a scan reconstruction, combine image data sets, toggle between image data sets, segment tissue of interest, etc.

FIGURE 3 schematically illustrates an example of moving structure of interest segmentor 224.

The moving structure of interest segmentor 224 includes storage 302, which stores projection data. The projection data can be from and/or generated by the imaging system 200 and/or other imaging system. Alternatively, the projection data can be from a data repository such as a picture archiving and communication system (PACS), a radiology information system (RIS), a hospital information system (HIS), etc. In a variation, the storage 302 is omitted and the projection data is provided to another component of the moving structure of interest segmentor 224.

The moving structure of interest segmentor 224 includes a first reconstructor 304. The first reconstructor 304 reconstructs the full set of projection data, producing first
image data. The full set of projection data may correspond to a 180 degree scan (i.e., 180
degrees plus a source fan) or other scan, including a scan that covers less than 180 degrees
and a scan that covers more than 180 degrees. The resulting image data provides lower
temporal resolution for the acquired projection data, relative to a reconstruction that uses only
a sub-portion of the full set of projection data.

The moving structure of interest segmentor 224 further includes a rendering
engine 312. The rendering engine 312, in the illustrated embodiment, visually displays in
human readable format the first image data via a display of the output device(s) 228 and/or
other display. The image data 102 of FIGURE 1 illustrates an example of a reconstruction of
a full set of projection data corresponding to a 180 degree scan. In this example, the
anatomical features are distinguishable since a 180 degree scan provides a complete set of
projections.

The moving structure of interest segmentor 224 further includes a second
reconstructor (partial scan) 306. The second reconstructor 306 reconstructs only a sub-
portion of the full set of projection data, producing second image data. An angle setting 308
and a location setting 310 identify the sub-portion. For example, where the projection data
corresponds to a 180 degree scan, the angle setting 308 identifies an angle of less than 180
degrees (e.g., 160 degrees, 90 degrees, 30 degrees, etc.) and the location setting 310 identifies
a point in time of the 180 degrees scan at which the angle of the angle setting 308 is centered
about.

By way of non-limiting example, in one instance, the angle setting 308 is 90
degrees and the location setting 310 is the central time point of the 180 degree scan.
FIGURES 4 and 5 graphically illustrate this. FIGURE 4 shows an example 180 degree scan
400 with the radiation source 208 that traverses from a 12 O'clock position 402 through a
central point in time at a 3 O'clock position 404 to a 6 O'clock position 406. FIGURE 5
shows an angular range 500 of 90 degrees, from 502 to 504, centered about the central point
in time of the 180 degree scan at the 3 O'clock position 404.

Returning to FIGURE 3, the angle setting 308 and/or the location setting 310
can be a default, a user preference, a protocol based, etc. setting. Alternatively, the angle
setting 308 and/or the location setting 310 is identified by a user input from a user, for
example, via the input device(s) 230. Generally, the angle setting 308 is less than the angular
range of the full scan. As a result, the second image data, relative of the first image data, will
have less motion artifact. Furthermore, since the time interval of the sub-portion is less than
the time interval of the full set of projection data, the second image data will have higher
temporal resolution, relative of the first image data.

The lower motion artifact and the higher temporal resolution are shown in
FIGURE 6. FIGURE 6 shows the same coronary artery 104 shown in FIGURE 1. However,
in FIGURE 6, the same coronary artery 104 is a smaller blurred arc 602 (more compact)
relative to the blurred arc 106 in FIGURE 1. Since less than 180 degrees of data is acquired,
the set of projections does not fill the 2D Fourier space, which leads to reconstruction errors.
This is shown in FIGURE 6 through the highly distorted anatomical structure, relative to the
anatomical structure of FIGURE 1.

Returning to FIGURE 3, the rendering engine 312 visually displays in human
readable format the second image data via a display of the output device(s) 228 and/or other
display. In one instance, the first image data and the second image data are concurrently
visually presented, for example, next to each other. This is shown in connection with
FIGURE 7. In another instance, only one of the first image data or the second image data is
visually presented at any given time. The user, via the input device(s) 230, can toggle back
and forth between the first image data and the second image data. The user uses the first
image data to identify a region of moving structure of interest and the second image data to
locate the moving structure of interest in the region.

In yet another instance, the first image data and the second image data are
fused or overlaid. In this instance, one or both of the first image data and the second image
data can have a transparency and/or opacity setting. The user can adjust the transparency
and/or opacity setting to visually emphasize or de-emphasize the first image data and/or the
second image data, including a user desired blend of both the first and the second image data.
Again, the user uses the first image data to identify a region of moving structure of interest
and the second image data to locate the moving structure of interest in the region.

Returning to FIGURE 3, the moving structure of interest segmentor 224
further includes a segmentor 314. The segmentor 314 allows a user to segment the moving
structure of interest. For this, the segmentor 314 receives a signal indicative of a region to
segment selected by the user. The region can be manually identified by the user (e.g.,
through free hand drawings, etc.) and/or automated segmentation software tools. In the latter
case, the user can accept, modify and/or reject the segmentation. The user, via the input
device(s) 230, can pan, zoom, rotate, and/or other manipulate the rendered image data to
facilitate segmentation.
The segmented moving structure of interest can be identified in one of the first or second image data and automatically placed in the other of the first or second image data as the first or second image data are inherently registered and share the same coordinate system. The segmented moving structure of interest can be propagated through a volume of axial images using the approach described above for each axial slice. In another instance, the above described approach is applied every other slice, every fifth slice, etc., with interpolation or other approach used to construct the segmentation there between.

In the illustrated embodiment, the segmented moving structure of interest is evaluated by the evaluation 226 instruction(s). For example, in one instance, the moving structure of interest includes at least one centerline of at least one coronary vessel, and the evaluation 226 instruction(s) evaluates the segmented moving structure of interest in connection with a quantitative evaluation of coronary disease. In another instance, for example, where the centerline is determined in different cardiac phases, the evaluation 226 instruction(s) evaluates the segmented moving structure of interest in connection with motion estimation and compensation.

In FIGURE 3, the first reconstructor 304 and the second reconstructor 306 are shown as two separate reconstructors. In a variation, the first reconstructor 304 and the second reconstructor 306 can be implemented with or are sub-reconstructors of the same reconstructor. Furthermore, one or more of the first reconstructor 304 and the second reconstructor 306 can be implemented via the reconstructor 216 (FIGURE 2).

FIGURE 8 shows a variation of FIGURES 4 and 5 in which a full scan 800 is greater than 180 degrees, and a sub-portion 810 is less than 90 degrees and is not centered on the full scan. In this example, the full scan starts at 802, passes a central location 806, and ends at 808. The sub-portion 810 covers a sub-range from 812 to 814 and is not centered at 806. The particular center point and angular range may correspond to the particular motion phase of interest, a tradeoff between temporal resolution and motion artifact, etc.

Although the above is described in connection with axial scans, it is to be understood that the above also applies to helical scans.

FIGURE 9 illustrates an example method in accordance with embodiments disclosed herein.

It is to be appreciated that the ordering of the acts in the methods is not limiting. As such, other orderings are contemplated herein. In addition, one or more acts may be omitted and/or one or more additional acts may be included.

At 902, projection data from a scan of a moving subject is obtained.
At 904, the projection data is reconstructed, generating first image data.
At 906, a sub-set of the project data is identified for a second reconstruction.
At 908, the sub-set of the projection data is reconstructed, generating second image data.
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At 910, the first image data is utilized to locate a region in which a moving structure of interest is located.
At 912, the second image data is utilized to locate the moving structure of interest within the region.
At 914, the moving structure of interest is segmented from one of the first or second image data.
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The segmented moving structure of interest can be further evaluated, as described herein.

The above methods may be implemented by way of computer readable instructions, encoded or embedded on computer readable storage medium, which, when executed by a computer processor(s), cause the processor(s) to carry out the described acts.
Additionally or alternatively, at least one of the computer readable instructions is carried by a signal, carrier wave or other transitory medium.

The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.
CLAIMS:

1. A method, comprising:
obtaining projection data from a scan of a moving structure of interest;
reconstructing the projection data, generating first image data;
identifying a sub-set of the projection;
reconstructing the sub-set projection data, generating second image data;
identifying a region in which the moving structure of interest is located based on the first image data; and
identifying a location of the moving structure of interest in the identified region based on the second image data.

2. The method of claim 1, wherein the first image data has a first temporal resolution and the second image data has a second temporal resolution, wherein the first temporal resolution is lower than the second temporal resolution.

3. The method of any of claims 1 to 2, wherein the first image data has a first level of motion artifact and the level of motion artifact, wherein the first level of motion artifact is greater than the second level of motion artifact.

4. The method of any of claims 1 to 3, comprising:
visually displaying, concurrently, the first image data and the second image data;
receiving an input signal indicating the location of the moving structure of interest in the second image data; and
automatically identifying the location of the moving structure of interest in the first image data based on the input signal.

5. The method of any of claims 1 to 3, comprising:
visually displaying only one of the first image data or the second image data;
receiving an input signal; and
switching between visual display of the first image data and the second image based on the input signal.

6. The method of any of claims 1 to 3, comprising:
   visually displaying the first image data and the second image data superimposed over each other;
   receiving an input signal indicative of at least one of an opacity or transparency level for at least one of the first image data and the second image data; and
   visually displaying the first image data and the second image data based on the input signal.

7. The method of any of claims 1 to 6, wherein the first image data corresponds to a 180 degree scan in which data is acquired for 180 degrees plus a source fan.

8. The method of any of claims 1 to 6, wherein the first image data corresponds to a scan greater than 180 degree.

9. The method of any of claims 7 to 8, wherein the second image data corresponds to less than the 180 degree scan.

10. The method of claim 9, wherein the subset of projection data is centered at a central time point of the projection data.

11. The method of any of claims 1 to 10, wherein the first image data includes a plurality of individual axial slices, and further comprising:
    propagating the identified location through the plurality of individual axial slices.

12. The method of any of claims 1 to 11, further comprising:
    segmenting the moving structure of interest, producing segmented moving structure of interest.

13. The method of claim 12, further comprising:
    performing a quantitative evaluation on the segmented moving structure of
14. The method of claim 12, further comprising:
   motion compensating at least one of the projection data or the first image data based on the segmented moving structure of interest.

15. A moving structure of interest segmentor (224), comprising:
   a first reconstructor (304) that reconstructs projection data corresponding to a scan of a moving structure, generating first image data;
   a second reconstructor (306) that reconstructs a sub-set of projection data, generating second image data;
   a rendering engine (312) that visually displays the first and the second image data;
   an input device(s) (230) that receives a first input indicative of a region in the first image data in which the moving structure of interest is located and a second indicative of a location within the region at which the moving structure of interest is located; and
   a segmentor (314) that segments the moving structure of interest based on the location of the moving structure of interest.

16. The moving structure of interest segmentor of claim 15, where the projection data corresponds to an angular range, and further comprising:
   an angle setting (308) that identifies a sub-portions of the angular range for the sub-set of projection data.

17. The moving structure of interest segmentor of claim 16, further comprising:
   a location setting (310) that identifies a time point of the projection at which the sub-portion is centered.

18. The moving structure of interest segmentor of any of claims 15 to 17, further comprising:
   a display, wherein the first image data and the second image data are concurrently visually displayed via the display,
   wherein the input device(s) receives an input signal indicating the location of the moving structure of interest in the second image data, and the rendering engine
automatically determines the location of the moving structure of interest in the first image
data based on the input signal.

19. The moving structure of interest segmentor of any of claims 15 to 17, further comprising:
   a display, wherein the first image data and the second image data are
   alternately visually displayed or simultaneously displayed superimposed.

20. A computer readable storage medium (222) encoded with one or more
    computer executable instructions, which, when executed by a processor of a computing
    system, causes the processor to:
    reconstruct at least two image data sets from different portions of a same set of
    projection data, wherein the at least two image data sets have different temporal resolution;
    locate moving structure of interest based on the at least two image data sets;
    and
    segment the moving structure of interest based on the located moving structure
    of interest.
Obtain projection data of scanned moving structure

Reconstruct the projection data, generating first image data

Identify a sub-set of the projection data

Reconstruct the sub-set, generating second image data

Locate region of moving structure from first image data

Locate moving structure in the region from second image data

Segment moving structure from the first or second image data

FIG. 9
**INTERNATIONAL SEARCH REPORT**

**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 G06T

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

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

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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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
- "B" earlier application or patent but published on or after the international filing date
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Name and mailing address of the ISA:

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### DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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