(12) UK Patent Application (19) GB (11) 2 365 736 (13) A

(43) Date of A Publication 20.02.2002

(21) Application No 0019147.8

(22) Date of Filing 05.08.2000

(71) Applicant(s)
X-Tek Systems Ltd
(Incorporated in the United Kingdom)
64-66 Akeman Street, Tring, HERTFORDSHIRE, HP23 6AF, United Kingdom

(72) Inventor(s)
Andrew Timothy Ramsey

(74) Agent and/or Address for Service
Saunders & Dolleymore
9 Rickmansworth Road, WATFORD, Herts, WD18 0JU, United Kingdom

(51) INT CL^7
A61B 6/03

(52) UK CL (Edition T)
H5R RTP RTS

(56) Documents Cited
GB2242106 A **GB 2043393 A**
EP 0860144 A2 **EP 0052342 A2**
EP 0004258 A1 **WO 88/04812 A1**

(58) Field of Search
UK CL (Edition S) **H5R RTP RTS**
INT CL^7 **A61B 6/03 , G06F 17/00 19/00**
Online: WPI, EPODOC, JAPIO

(54) Abstract Title
Computed tomography

(57) A method of generating a CT image of an object, comprising acquiring radiographic images of the object from a number of different angular directions; and processing the images cumulatively, initially from images taken at relatively high angular increments and subsequently adding data from images at relatively lower angular increments to cumulatively build up a reconstructed data set, whereby a data set of progressively higher resolution is obtained and is available for viewing throughout this process.

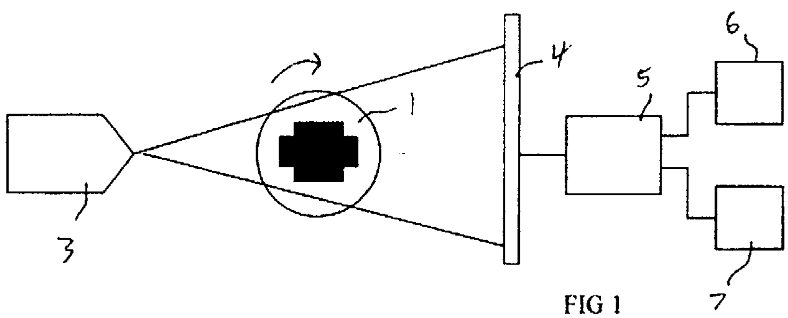

FIG 1

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1/1

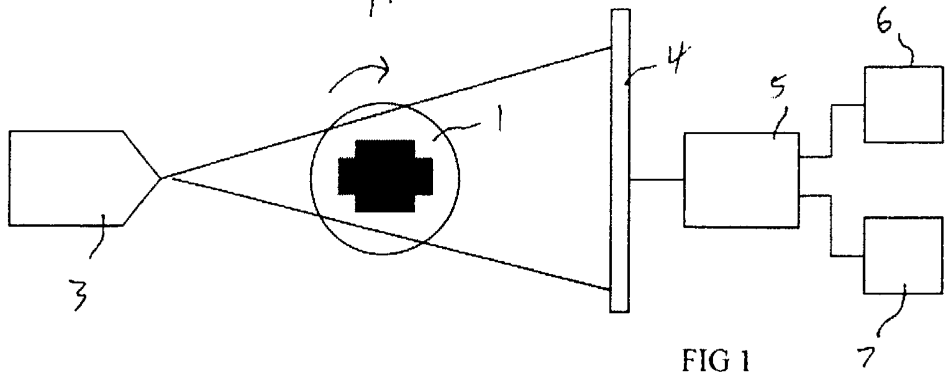


FIG 1

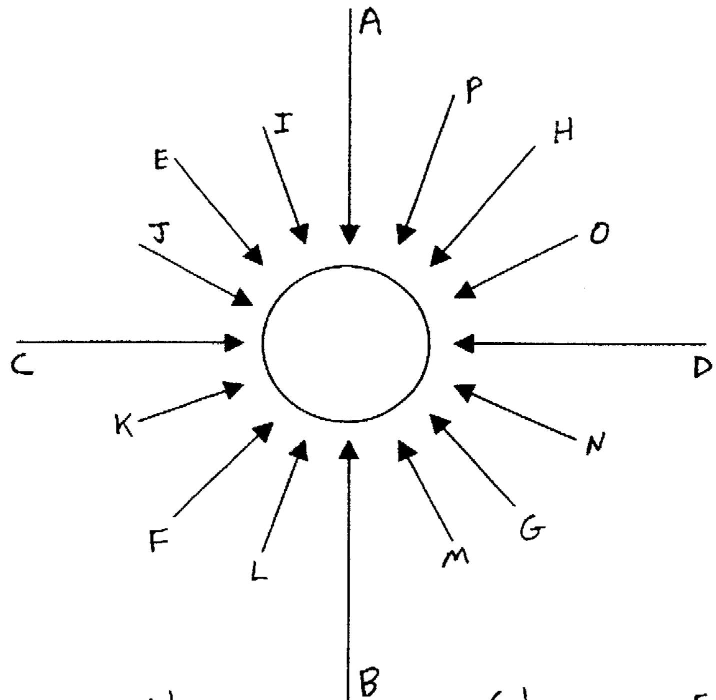
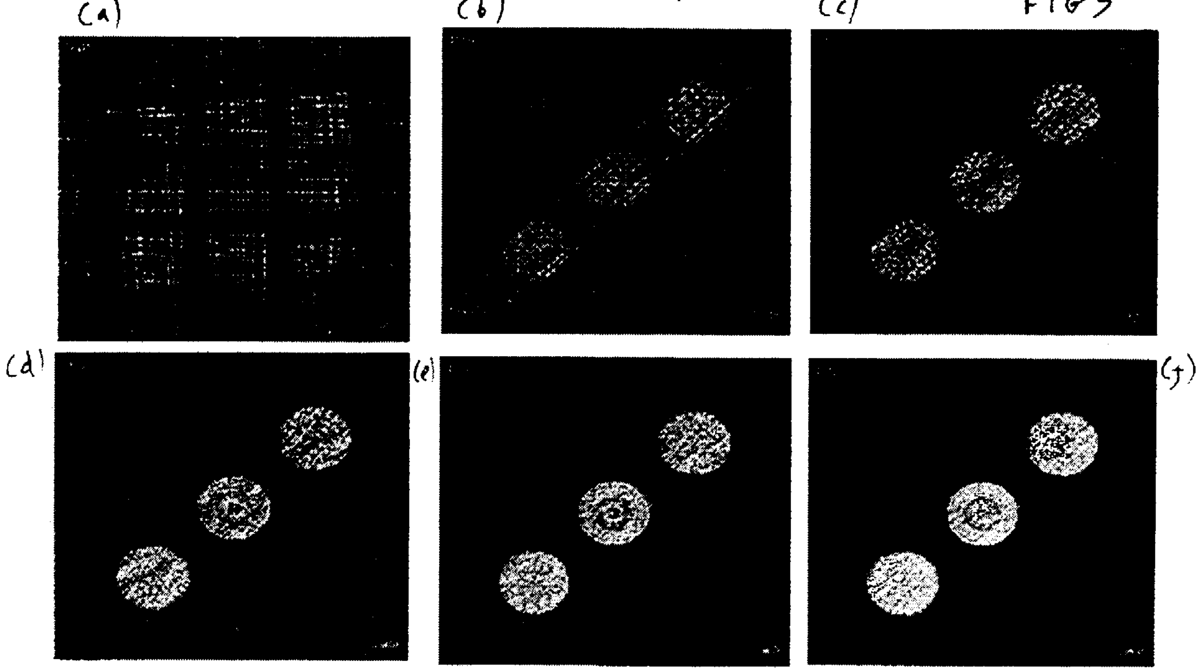


FIG 2

FIG 3



COMPUTED TOMOGRAPHY

This invention relates to computed tomography. In particular, it relates to acquiring and viewing a 3D tomographic data set.

Computed tomography (CT) is a process of acquiring, by the use of penetrating radiation, a series of radiographic images of an object viewed from different angles and the subsequent computer processing of these images to generate a three-dimensional model of the internal structure of the object, or a series of two-dimensional slices through the object. The penetrating radiation is usually X-ray radiation. The most common use of CT is in medical imaging, in so called "body scanners", although the processes is also used in industrial inspection (non-destructive testing).

In industrial tomography, a series of images are built up from different angles and this can be done by either moving the radiation source and detector, and keeping the object stationary or by having a fixed radiation source and detector and by rotating the object through 180° or 360° in small steps, a radiographic image being acquired at each angular step.

This is shown schematically in Figure 1. An object 1 is in the pathway of an X-ray beam 2 generated at an X-ray source 3. The X-rays are detected at a detector 4 to generate an image. The detector is connected to (or forms part of) a processing means, such as a computer 6, a display 7 and an image recorder 8 (eg a printer and/or disk drive)

A first radiographic image is obtained at a first projection angle and this image is stored in memory, or more commonly, on a data carrier such as a disk. The object is then rotated slightly, perhaps by 1° or 2°, and then a further image is acquired and stored. This then proceeds until the image has been rotated through 180° or 360°. Once all the images have been acquired, a reconstruction algorithm is run which extracts information from each image in turn and processes it to generate a three-dimensional model or a series of two-dimensional slices.

This process can be very slow since first of all an entire set of images at various angles have to be acquired and then a reconstruction algorithm has to be run on each of these images in order to extract information to generate the three-dimensional or two-dimensional model. In practice, each of these steps can take several hours or more for relatively large or complex objects. Only at the end of the process can the user view an image and he may find at that stage that he has been looking at the wrong part of an object and therefore the processes needs to be repeated.

The present invention arose in an attempt to provide an improved method of processing tomographic data.

According to the present invention there is provided a method of generating a CT image of an object, comprising acquiring radiographic images of the object from at least two angular directions; and processing the images cumulatively, initially from images taken at relatively high angular increments and subsequently adding data from images at relatively lower angular increments to cumulatively build up a reconstructed data set, whereby a data set of progressively higher resolution is obtained.

Processing of the images may begin while data acquisition is taking place, and may commence immediately after a first image has been acquired.

In other embodiments, processing may be done on a complete set of acquired images.

According to the present invention there is further provided a method of reconstructing a three-dimensional data set from CT imaging of an object, comprising initially cumulatively adding results from large angular incremental scans of the object and progressively adding results from progressively smaller angular incremental scans.

According to the present invention in a further aspect there is provided a method of reconstructing a three-dimensional data set from CT scanning of an object, comprising cumulatively processing and obtaining data sets of the object from different angular directions whilst data acquisition is still continuing.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows schematically X-ray apparatus for obtaining CT images of an object;

Figure 2 shows the directions of repeated scans at different angles of an object; and

Figure 3 shows a series of two-dimensional cross-sections through a volume data set filled with projection data of a sample comprising three spheres after different numbers of projections.

As described with reference to Figure 1, computed tomography is the process of acquiring, using penetrating radiation, a series of radiographic images of an object viewed from different angles. The object 1 (Figure 1) is placed between a radiation source and a detector and, assuming the source and detector are fixed, a large number of images at different projection angles are acquired in a conventional CT process. Once all these images have been acquired, then they are processed in order to obtain a three-dimensional model or a series of two-dimensional slices. There are several known methods of reconstructing projection data, the most common of which is called filtered back projection, since it is simple to implement, but this is computationally intensive and therefore slow.

In embodiments of the invention, each projection at a particular angle can be processed independently and, since acquisition geometry is known at the start of acquisition, a reconstruction process preferably begins as soon as the first projection image is acquired. Thus, referring to Figure 2, in one example according to the present invention, a first projection image is obtained in direction A across the image. The X-ray source and detector (computer) are not shown in this figure for clarity. After this image has been acquired, the object is rotated through a first relatively large increment, which in the figure is 180° so that a second acquisition is then taken in direction B. For small to medium resolution data sets and a sufficiently powerful computer, the resolution of one projection image (ie the image in direction A) can be completed during the acquisition of the next projection image from direction B and thus reconstruction can keep pace with acquisition. As computing power increases, the resolution at which this is possible also increases. After the first set of widely angularly spaced requisitions, further sets at increasingly smaller angular increments may be taken. Thus, in a second pass a first acquisition in direction C (90° to direction A) is acquired. The next acquisition would then be 90° from this, ie at 180° but as this acquisition has already been done (B) this is not required to be done and so the next acquisition is at 270°, in direction D. A further acquisition is made in direction E (45°), F (135°), G (225°) and H (315°). A further set of increasingly smaller angular increments is then taken in direction I (22.5°), J (67.5°), and so on.

By acquiring the projection images in a specific order, notably full rotation of the object using successfully smaller angular increments, successfully higher resolution volumes can be shown, starting with very low resolution and gradually building up to full resolution. As stated, since some projection angles will have already been used during the larger angular increment runs, they do not need to be collected again during the lower angular increment runs.

Although in the example shown, the first rotation is at angular increment of 180°, it will often been found that any object in the reconstructed volume would not normally be recognisable until the angular increment was less than 20°. Thus, in practical embodiments, the start point is a full rotation (or rotation through 180°) at an angular increment of about 20°, followed by successive sets of acquisitions at intermediate angles.

Accordingly, after only a small number of projection angles, a view of the object becomes visible in the reconstruction volume, and this view can be used immediately. Although the resolution after the first few passes will not be sufficient to pick out fine detail in an object, it may be sufficient to pick out large catastrophic faults or indeed to identify whether the correct part of an object or even whether the correct object, is being viewed. This can save considerable time and expense if it can found out at an earlier stage that the wrong part of an object is being viewed, since corrective steps can then be taken. Since the volume data can begin to appear immediately after the first acquisition (eg the acquisition in direction A) then great economies in time and expense can be made.

Figure 3 shows six two-dimensional cross-sections through a volume data set which is filled with the projection of a sample consisting of three spheres after, respectively, 4, 8, 16, 32, 64 and 120 projections. As shown at 3(a), after just four projections, the image is not immediately recognisable as consisting of three spheres. After eight projections (3b), three vaguely circular objects begin to appear more prominently and after sixteen projections (3c), these circles (being two-dimensional slices through spheres) begin to show more clearly. As more and more projections begin to be used in the reconstruction, the images become of greater quality and higher resolution.

By allowing the user to further interact with the data set, two-dimensional views at varying heights and angles through a data set can be viewed. With a sufficiently powerful computer, rendered views of the three-dimensional data set can be available. The view can be updated whenever a new projection data set is added, or whenever the user wishes to change slice position, orientation, enhancement or other parameters.

By providing a dynamically growing data set, by virtue of beginning to process the data whilst acquisition is still continuing, any problems with the data, the acquisition geometry, reconstruction parameters or other factors become visible much more quickly than before and there is no longer any need to wait until the end of reconstruction or the end of acquisition to spot such problems. Only if a precise measurement of defect sizes or very small scale defects are required to be monitored, need a whole set of projection images be acquired and processed.

In a modification, techniques according to the invention can be applied to previously acquired data sets. Once an entire data set has been acquired then, by reconstructing projection images firstly from very widely spaced angular projections and subsequently through more finely spaced angular projections, an idea of the result can be seen very quickly so that various reconstruction parameters such as viewing the wrong volume, can be spotted earlier, fixed and the reconstruction started, thus saving a considerable amount of time.

CLAIMS

1. A method of generating a CT image of an object, comprising acquiring radiographic images of the object from at least two angular directions; and processing the images cumulatively, initially from images taken at relatively high angular increments and subsequently adding data from images at relatively lower angular increments to cumulatively build up a reconstructed data set, whereby a data set of progressively higher resolution is obtained.

2. A method as claimed in Claim1, wherein processing of the data set begins after just one acquisition has been made.

3. A method as claimed in any preceding claim, wherein the reconstructed data set is displayed on a display and the display is updated each time a new projection image is cumulatively added, such that a view of the volume data set as it is being reconstructed is available.

4. A method as claimed in any preceding claim, wherein processing is begun whilst data acquisition is taking place.

5. A method as claimed in any of Claims 1 to 3, wherein processing is begun after all images have been acquired.

6. A method as claimed in any preceding claim, wherein the chosen increments are varied after a full or half rotation, relative to the object, has been made.

7. A method as claimed in any preceding claim, wherein after each relative rotation of the object the angular increment is halved.

8. A method as claimed in any preceding claim, wherein for each set of angular acquisitions in a rotation, images at any angular directions for which images have been already taken are omitted in that set of angular projections.

9. A method of reconstructing a three-dimensional data set from CT imaging of an object, comprising initially cumulatively adding results from large angular incremental scans of the object and progressively adding results from progressively smaller angular incremental scans.

10. A method of reconstructing a three-dimensional data set from CT scanning of the object, comprising cumulatively processing and obtaining data sets of the object from different angular directions whilst data acquisition is still continuing.

11. A method as claimed in Claim 9, comprising displaying the data sets as they are processed, to obtain a displayed image of progressively greater resolution.

12. A computer program product, comprising means for receiving data representative of

radiographic images of an object from at least two angular directions, and means for processing the images cumulatively, initially from images taken at relatively high angular increments and subsequently adding data from images at relatively lower angular increments to cumulatively build up a reconstructed data set, whereby a data set of progressively higher resolution is obtained.

13. A computer program product as claimed in Claim 12, adapted to begin processing the data set whilst data acquisition is taking place.

14. A computer program product as claimed in Claim 12, adapted to begin processing the data set after all images have been acquired.

15. CT apparatus, including a computer program product as claimed in any of Claims 12 to 14.

16. CT apparatus, including means for acquiring radiographic images of an object from at least two angular directions, and means for processing the images cumulatively, initially from images taken at relatively high angular increments and subsequently adding data from images at relatively lower angular increments to cumulatively build up a reconstructed data set, whereby a data set of progressively higher resolution is obtained.

17. A method of obtaining CT images substantially as hereinbefore described, with reference to, and as illustrated by, the accompanying drawings.

Application No:	GB 0019147.8	**Examiner:**	Brian Mc Cartan
Claims searched:	1 - 17	**Date of search:**	26 February 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H5R (RTP, RTS)

Int Cl (Ed.7): A61B (6/03) G06F (17/00, 19/00)

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2242106 A	HITACHI Claims 1 - 3 in particular	1 & 16
X	GB 2043393 A	SIEMENS Claim 1 and description	1 & 16
X	EP 0860144 A2	FREEMAN See abstract	1 - 17
X	EP 0052342 A2	TOKYO See abstract	1, 2, 4, 5 & 16
X	EP 0004258 A1	SIEMENS See abstract	1 - 5, 12, 13 & 16
X	WO 88/04812 A1	YOKOGAWA See abstract	1, 2, 4, 5, 12, 13 & 16

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