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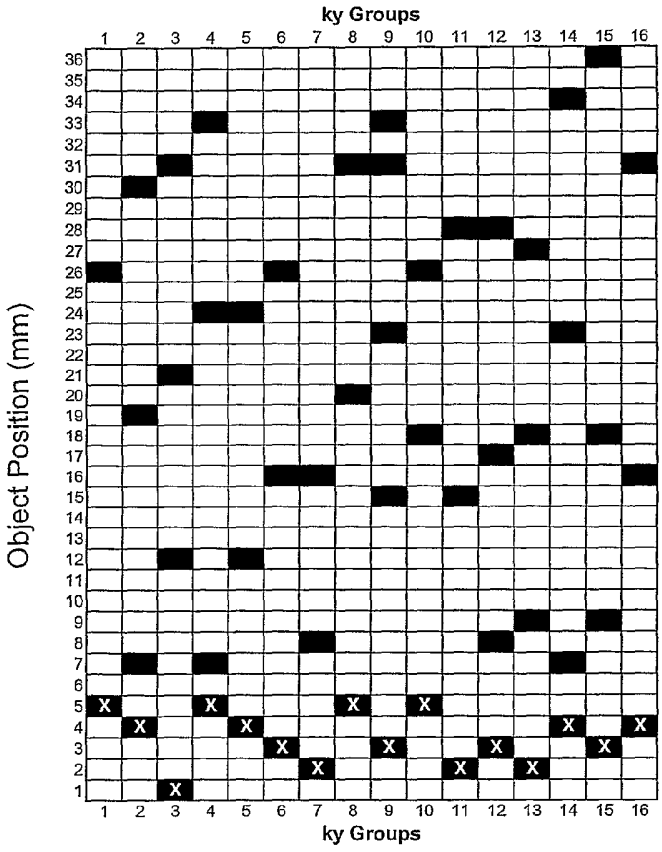
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(54) Title: CAPTURE OF MRI IMAGES



(57) Abstract: A method of producing an MRI image of an object in cyclic motion by acquiring data in k-space according to the measured position of the object, and an analysis of data previously acquired. The invention also provides a magnetic resonance imaging heart monitor configured to use the method.

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MAGNETIC RESONANCE IMAGING OF AN OBJECT IN CYCLIC MOTION

Field of the Invention

The invention relates to image acquisition for magnetic resonance imaging (MRI), and in particular to a motion-resistant technique for image capture.

Background and Prior Art known to the Applicant

Magnetic resonance imaging has become established as a key technique for imaging the soft tissues of the body. MRI images are predominantly formed by the measurement of radio frequency signal emission during proton spin relaxation following an excitation signal to protons located in a magnetic field. The use of magnetic field gradients allows spatially encoded data to be acquired to form an image. The data are acquired in so-called "k-space", related via Fourier transform to the physical space from where an image is acquired – different positions in "k space" correspond to spatial frequency and phase information. The task of forming an MRI image can be viewed as acquiring lines in k-space ("ky lines") to span the entire k-space to be imaged, and then reconstructing the spatial image by Fourier transform.

The physics underlying magnetic resonance imaging relies on the relaxation time of protons (or, occasionally, the relaxation time of other NMR active nuclei), and so acquisition of sufficient data to form an image takes significant time in relation to expected movement of a subject to be imaged, such as a human body. This problem is particularly acute when imaging structures within the thorax of a subject, as they are subject to cyclic motion from the subject's breathing during a typical timescale for image acquisition. The problem is further exacerbated in the field of cardiac imaging, where the beating of the heart adds a second cyclic motion to the problem.

The problem has been addressed by the use of so-called 'navigator acceptance' imaging methods in which positional information is gathered effectively simultaneously with image data, but these have been hindered by the loss in scan efficiency which results from the changes in breathing pattern during a scan. The technique known as 'phase ordering with automatic window selection' (PAWS) provides a method which is resistant to changes in breathing whilst allowing the user the use of phase ordering to provide effective motion artefact reduction in an optimal time (Jhooti P, Gatehouse PD, Keegan J, Bunce NH, Taylor AM, Firmin DN. "Phase ordering with automatic window selection (PAWS): a novel motion-resistant technique for 3D coronary imaging", *Magnetic Resonance in Medicine*, 2000, March, 43(3):470-80.). The drawback of the PAWS technique is that images are only available once enough data has been acquired within the range of motion specified. Whilst the acquisition may terminate with the optimal scan time for the particular respiratory trace and acceptance window size, this optimal time may still be quite long.

Other techniques such as the Diminishing Variance Algorithm (DVA) acquire the whole image before attempting to limit the respiratory motion (Sachs TS, Meyer CH, Irarrazabal P, Hu BS, Nishimura DG, Macovski A., "The diminishing variance algorithm for real-time reduction of motion artefacts in MRI", *Magnetic Resonance in Medicine*, 1995, 34:412-422). Whilst DVA has the advantage of allowing scans to terminate at any point after the initial image has been corrected, the algorithm has been found to be less effective in subjects with a variable respiratory pattern (Jhooti *et al*, ibid).

These navigator acceptance imaging methods are invariably compromised when the breathing pattern of a subject changes during the scan. Techniques such as PAWS have attempted to overcome such problems by the use of automatic sampling strategies which make no assumptions as to the final acceptance window. As all possible windows are treated with equal importance, the techniques have been shown to be effective in situations of changes of respiration whilst also allowing scans to terminate in an optimal time. However, as this technique focuses on its final optimal image, no image is available until this has been acquired.

The DVA algorithm attempts to provide an image as soon as possible, and then to continually improve this image until a particular range of motion is achieved, or scan quality is deemed to be satisfactory. However, as this techniques makes a decision as to which range of motion will be accepted, and further acquisitions made accordingly, the situation is unsuitable in situations of respiratory change. A technique is therefore required to overcome these disadvantages.

The present invention attempts to combine the noted benefits of the DVA and PAWS technique to provide a methodology that enables images to be reconstructed quickly, and with all further data acquisition reducing the acceptance window and improving image quality, whilst ensuring that a scan terminates automatically in an optimal scan time for a given acceptance window size regardless of respiratory pattern.

Summary of the Invention

The invention provides improved scan efficiency by a ContinuousLy Adaptive Windowing Strategy, hence termed CLAWS.

Accordingly, the invention provides a method of generating a magnetic resonance image of an object in cyclic motion, comprising the steps of:

(a) defining a desired acceptance window corresponding to an extent of motion over which image data may be combined;

(b) defining a series of position bands, together covering the total range of expected motion, to enable object positions within that range to be assigned to one

of said bands, the range of motion corresponding to at least one of said bands being less than or equal to the acceptance window;

(c) selecting a required image resolution, thus defining the number of ky lines to be acquired;

(d) acquiring ky data and object position data according to a first phase of data collection, comprising the steps of:

(1) generating an acquisition order for a first set of ky lines (the "first pass acquisition order"), such that each ky line to be acquired is included once in the order;

(2) measuring the object position, and determining which position band corresponds to said object position;

(3) substantially simultaneously with step (d)(2), acquiring ky data corresponding to the next ky line in the first pass acquisition order;

(4) storing the object position and ky data so acquired;

(5) repeating the method from step (d)(2) until data have been collected for all ky lines;

(e) acquiring ky data and object position data according to a second phase of data collection, comprising the steps of:

(1) measuring the object position, and determining which position band corresponds to said object position (the "current position");

(2) determining, from previously collected data, the ky line or lines (the "candidate lines") for which the ky data collected closest to the current position (the "most proximate data") is farthest away from the current position, and choosing this, or one of these candidate lines to be the next ky line to be acquired;

(3) substantially simultaneously with step (e)(1), acquiring ky data corresponding to the next ky line so chosen;

(4) storing the object position and ky data so acquired;

(5) if all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines, otherwise,

(6) repeating the method from step (e)(1) onwards until all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines within the acceptance window.

Preferably, and where there is a plurality of candidate lines, the choice of which of the candidate lines is to be acquired is made according to at least one criterion selected from the group comprising:

(A) counting the number of acquisitions already made for each candidate ky line, and selecting the candidate ky line or lines with the fewest acquisitions;

(B) determining the average distance of previous acquisitions for each candidate line to the current position, and selecting the ky line or lines with the greatest average distance from the current position;

Advantageously also, and where the distance between the farthest most proximate data and the current position is less than the desired acceptance window, the method further comprises the step of choosing the next line to be acquired according to at least one criterion selected from the group comprising:

(A) determining the set of contiguous ky lines, corresponding to a position range equal to the desired acceptance window, having the most number of prior ky line acquisitions (the "most frequent window"); measuring the distance between the most frequent window to the most proximate data for each candidate ky line; and selecting the ky line or lines with the furthest most proximate data to the most frequent window;

(B) determining the number of previous acquisitions for each of the candidate ky lines, and selecting the ky line or lines with the fewest acquisitions; and

(C) determining the average distance of previous acquisitions from the current position for each ky line, and selecting the ky line with the largest average distance.

Included within the scope of the invention is a method of generating a magnetic resonance image of an object in cyclic motion, comprising the steps of:

(a) defining a desired acceptance window corresponding to an extent of motion over which image data may be combined;

(b) defining a series of position bands, together covering the total range of expected motion, to enable object positions within that range to be assigned to one of said bands, the range of motion corresponding to at least one of said bands being less than or equal to the acceptance window;

(c) selecting a required image resolution, thus defining the number of ky lines to be acquired;

(d) acquiring ky data and object position data according to a first phase of data collection, comprising the steps of:

(1) generating an acquisition order for a first set of ky lines (the "first pass acquisition order"), such that each ky line to be acquired is included once in the order;

(2) measuring the object position, and determining which position band corresponds to said object position;

(3) substantially simultaneously with step (d)(2), acquiring ky data corresponding to the next ky line in the first pass acquisition order;

(4) storing the object position and ky data so acquired;

(5) repeating the method from step (d)(2) until data have been collected for all ky lines;

(e) acquiring ky data and object position data according to a second phase of data collection, comprising the steps of:

(1) measuring the object position, and determining which position band corresponds to said object position (the "current position");

(2) determining, from previously collected data, the ky line or lines (the "candidate lines") for which the ky data collected closest to the current position (the "most proximate data") is farthest away from the current position;

(3) if the distance between the farthest most proximate data and the current position is less than the desired acceptance window, then choosing the next ky line to be acquired from the candidate lines according to "Scheme B", otherwise:

(4) if more than one such ky line are determined to have equal farthest most proximate data, then choosing the next ky line to be acquired from the candidate lines according to "Scheme A", otherwise:

(5) choosing the ky line with the farthest most proximate data to be the next line to be acquired;

(6) substantially simultaneously with step (e)(1), acquiring ky data corresponding to the next ky line so chosen;

(7) storing the object position and ky data so acquired;

(8) if all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines, otherwise,

(9) repeating the method from step (e)(1) onwards until all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines within the acceptance window.

wherein "Scheme A" comprises the steps of:

(A1) counting the number of acquisitions already made for each candidate ky line;

(A2) selecting the candidate ky line or lines with the fewest acquisitions;

(A3) if only one such ky line is selected, then choosing that line as the next line to be acquired; otherwise

(A4) determining the average distance of previous acquisitions for each candidate line to the current position;

(A5) selecting the ky line or lines with the greatest average distance from the current position;

(A6) if only one such ky line is selected, then choosing that line as the next line to be acquired; otherwise choosing any of these lines;

and wherein "Scheme B" comprises the steps of:

(B1) determining the set of contiguous ky lines, corresponding to a position range equal to the desired acceptance window, having the most number of prior ky line aquistions (the "most frequent window");

(B2) measuring the distance between the most frequent window to the most proximate data for each candidate ky line;

(B3) selecting the ky line or lines with the furthest most proximate data to the most frequent window;

(B4) if only one such ky is selected, then choosing that line as the next line to be acquired; otherwise

(B5) determining the number of previous acquisitions for each of the candidate ky lines;

(B6) selecting the ky line or lines with the fewest acquisitions;

(B7) if only one such ky is selected, then choosing that line as the next line to be acquired; otherwise

(B8) determining the average distance of previous acquisitions from the current position for each ky line;

(B9) selecting the ky line with the largest average distance;

(B10) if only one such ky line is selected, then choosing that line as the next line to be acquired; otherwise choosing any of these lines.

In this aspect of the invention, it has been found that the particular combination and ordering of steps in the method leads to especially rapid and reliable image acquisition.

In any method described above, it is preferable that, following each acquisition of ky data in the second phase of data collection, an image is created and displayed using acquired ky data spanning the smallest range of object positions. More preferably, the method further comprises the step of allowing an operator, in us, to terminate image acquisition after displaying an image.

In any method described above, it is preferable that the first pass acquisition order is chosen to initially collect data in the central portion of ky space, thereby allowing intermediate images to be created and displayed, albeit with a reduced spatial frequency bandwidth, before all ky lines have been acquired.

Also in any method described above, it is preferable that the first pass acquisition order is chosen to initially collect data in a stepwise fashion across ky space, thereby allowing intermediate images to be created and displayed, albeit with a reduced resolution, before all ky lines have been acquired.

In particularly preferred embodiments, the invention provides a magnetic resonance imaging heart monitor configured to use a method described above.

Also included within the scope of the invention is a method of generating a magnetic resonance image substantially as described herein with reference to and as illustrated by any appropriate combination of the accompanying drawings.

Whilst the above description uses the terminology of acquiring ky lines, it should be understood that the method also applies to the acquisition of groups of ky lines; this is the terminology used in figure 3.

Also, whilst the term "ky lines" has been used throughout this specification, and in the claims, it should be understood that this is not intended to limit the scope of the invention to any particular spatial direction, and should be taken to include other directions including those often referred to in the art as "kx lines" and "kz lines".

Brief Description of the Drawings

The invention will be described with reference to the accompanying drawings, in which:

Figure 1 is a graph showing the position of a target object to be imaged during a period of data acquisition.

Figure 2(a) to 2(d) are diagrams illustrating, schematically, data acquisition and formation of an MRI image; and

Figure 3(a) to 3(c) are flow diagrams illustrating embodiments of the method of the present invention.

Description of Preferred Embodiments

The invention will be described with reference to one particular application of the method: the acquisition of magnetic resonance images of the heart, in the face of cyclic motion of the heart within the chest cavity caused by a patient's breathing. In this situation, movements of the heart are two-fold; firstly, the beating of the heart and secondly, movement of the organ throughout a breathing cycle. Motion artifacts caused by the beating of the heart may be readily removed by synchronizing the data acquisition cycles with the heart beat, i.e. data acquisition may be triggered by the cardiac cycle itself. This technique is known, and it is the second motion of the heart caused by breathing that remains to be solved.

The position of the heart relative to the MRI scanner may conveniently be determined by measuring a position of a datum point in the body; typically this might be the position of the diaphragm, which moves little relative to the heart, and which can be measured by an MRI line image. Figure 1 illustrates the movement of the diaphragm of a patient (and thus also the heart) during a period of data acquisition. It can be seen that, although the pattern of breathing, and thus movement, is relatively slow and regular over the first 20 or so acquisitions, breathing then becomes more erratic, and the pattern of movement changes over the acquisition period.

In this case, a method of generating a magnetic resonance image of the heart was used employing the scheme outlined in figure 3.

Figure 2(a) illustrates the position after 16 acquisition cycles. It can be seen that data were acquired sequentially from ky line positions 1 through to 16, and so the position data mirrors that of the object position shown in figure 1 for these acquisitions, in this example, each ky line position from 1 to 16 is represented by a column in the grid and each potential object position is then represented by a row in the grid labeled 1 to 36. Each object position spans a distance of 1mm, and thus the complete grid represents an object movement range of 36mm. The filled-in squares in the grid represent object positions and ky lines for which data have been acquired. The set of such positions also marked with an 'X' represents a complete set of ky lines spanning the smallest range of

object positions – i.e. the set of lines from which an image may be formed. It can be seen from figure 2(a) therefore that after 16 cycles, an image may be formed corresponding to a range of object positions from row 2 to row 28, i.e. spanning a distance of 27mm. In this example, the desired acceptance window was set at 5mm and so further acquisitions are required. In this example, it can be seen that the 'most frequent window', i.e. a window, the width of the desired acceptance window, that contains the most acquisitions, is located between positions 26 to 30, this 5mm window containing 5 acquisitions.

Figure 2(b) illustrates the situation after 38 acquisition cycles. It can be seen in this figure that a complete image may be formed using ky data in rows 2 to 12; this is the minimum window that contains an acquisition for each of the 16 ky lines. In this case it spans a distance of 11mm and so further acquisitions are required to generate an image within the desired acceptance window.

Figure 2(c) illustrates the situation after 50 acquisition cycles. It can be seen from figure 1 that for acquisition number 50, the diaphragm position was at 5mm. Following the algorithm, it can be seen that the ky line with the furthest most proximate data is line 3, having had its nearest acquisition at position 1. However, this distance is within the desired acceptance window of 5mm, and so a decision is made according to 'Scheme B' illustrated in figure 3(c). In this case, ky groups number 2 and 4 are the only groups that have not been acquired within the most frequent window and, as ky group number 2 has been acquired more times than 4 (3 times, as opposed to twice) ky group number 4 is acquired in this instance. Following this acquisition, it can be seen that a complete image may be formed using ky data from object positions 1 to 7, i.e. a window size of 6mm. Again, this is still not within the desired acceptance window and so further acquisitions are required.

Figure 2(d) shows the situation after 59 acquisition cycles. At this stage, it can be seen that a complete set of ky lines is available in positions 1 to 5, i.e. corresponding to a position range of 5mm. As this is the desired acceptance window size, data acquisition may be stopped and an image displayed.

CLAIMS

1. A method of generating a magnetic resonance image of an object in cyclic motion, comprising the steps of:

(a) defining a desired acceptance window corresponding to an extent of motion over which image data may be combined;

(b) defining a series of position bands, together covering the total range of expected motion, to enable object positions within that range to be assigned to one of said bands, the range of motion corresponding to at least one of said bands being less than or equal to the acceptance window;

(c) selecting a required image resolution, thus defining the number of ky lines to be acquired;

(d) acquiring ky data and object position data according to a first phase of data collection, comprising the steps of:

(1) generating an acquisition order for a first set of ky lines (the "first pass acquisition order"), such that each ky line to be acquired is included once in the order;

(2) measuring the object position, and determining which position band corresponds to said object position;

(3) substantially simultaneously with step (d)(2), acquiring ky data corresponding to the next ky line in the first pass acquisition order;

(4) storing the object position and ky data so acquired;

(5) repeating the method from step (d)(2) until data have been collected for all ky lines;

(e) acquiring ky data and object position data according to a second phase of data collection, comprising the steps of:

(1) measuring the object position, and determining which position band corresponds to said object position (the "current position");

(2) determining, from previously collected data, the ky line or lines (the "candidate lines") for which the ky data collected closest to the current position (the "most proximate data") is farthest away from the current position, and choosing this, or one of these candidate lines to be the next ky line to be acquired;

(3) substantially simultaneously with step (e)(1), acquiring ky data corresponding to the next ky line so chosen;

(4) storing the object position and ky data so acquired;

(5) if all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines, otherwise,

(6) repeating the method from step (e)(1) onwards until all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines within the acceptance window.

2. A method according to claim 1, where there is a plurality of candidate lines, and the choice of which of the candidate lines is to be acquired is made according to at least one criterion selected from the group comprising:

(A) counting the number of acquisitions already made for each candidate ky line, and selecting the candidate ky line or lines with the fewest acquisitions;

(B) determining the average distance of previous acquisitions for each candidate line to the current position, and selecting the ky line or lines with the greatest average distance from the current position;

3. A method according to claim 1, and where the distance between the farthest most proximate data and the current position is less than the desired acceptance window, further comprising the step of choosing the next line to be acquired according to at least one criterion selected from the group comprising:

(A) determining the set of contiguous ky lines, corresponding to a position range equal to the desired acceptance window, having the most number of prior ky line acquisitions (the "most frequent window"); measuring the distance between the most frequent window to the most proximate data for each candidate ky line; and selecting the ky line or lines with the furthest most proximate data to the most frequent window;

(B) determining the number of previous acquisitions for each of the candidate ky lines, and selecting the ky line or lines with the fewest acquisitions; and

(C) determining the average distance of previous acquisitions from the current position for each ky line, and selecting the ky line with the largest average distance.

4. A method of generating a magnetic resonance image of an object in cyclic motion, comprising the steps of:

(a) defining a desired acceptance window corresponding to an extent of motion over which image data may be combined;

(b) defining a series of position bands, together covering the total range of expected motion, to enable object positions within that range to be assigned to one of said bands, the range of motion corresponding to at least one of said bands being less than or equal to the acceptance window;

(c) selecting a required image resolution, thus defining the number of ky lines to be acquired;

(d) acquiring ky data and object position data according to a first phase of data collection, comprising the steps of:

(1) generating an acquisition order for a first set of ky lines (the "first pass acquisition order"), such that each ky line to be acquired is included once in the order;

(2) measuring the object position, and determining which position band corresponds to said object position;

(3) substantially simultaneously with step (d)(2), acquiring ky data corresponding to the next ky line in the first pass acquisition order;

(4) storing the object position and ky data so acquired;

(5) repeating the method from step (d)(2) until data have been collected for all ky lines;

(e) acquiring ky data and object position data according to a second phase of data collection, comprising the steps of:

(1) measuring the object position, and determining which position band corresponds to said object position (the "current position");

(2) determining, from previously collected data, the ky line or lines (the "candidate lines") for which the ky data collected closest to the current

position (the "most proximate data") is farthest away from the current position;

(3) if the distance between the farthest most proximate data and the current position is less than the desired acceptance window, then choosing the next ky line to be acquired from the candidate lines according to "Scheme B", otherwise:

(4) if more than one such ky line are determined to have equal farthest most proximate data, then choosing the next ky line to be acquired from the candidate lines according to "Scheme A", otherwise:

(5) choosing the ky line with the farthest most proximate data to be the next line to be acquired;

(6) substantially simultaneously with step (e)(1), acquiring ky data corresponding to the next ky line so chosen;

(7) storing the object position and ky data so acquired;

(8) if all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines, otherwise,

(9) repeating the method from step (e)(1) onwards until all ky lines have been collected within the desired acceptance window, then creating and displaying an image using the ky lines within the acceptance window.

wherein "Scheme A" comprises the steps of:

(A1) counting the number of acquisitions already made for each candidate ky line;

(A2) selecting the candidate ky line or lines with the fewest acquisitions;

(A3) if only one such ky line is selected, then choosing that line as the next line to be acquired; otherwise

(A4) determining the average distance of previous acquisitions for each candidate line to the current position;

(A5) selecting the ky line or lines with the greatest average distance from the current position;

(A6) if only one such ky line is selected, then choosing that line as the next line to be acquired; otherwise choosing any of these lines;

and wherein "Scheme B" comprises the steps of:

(B1) determining the set of contiguous ky lines, corresponding to a position range equal to the desired acceptance window, having the most number of prior ky line aquistions (the "most frequent window");

(B2) measuring the distance between the most frequent window to the most proximate data for each candidate ky line;

(B3) selecting the ky line or lines with the furthest most proximate data to the most frequent window;

(B4) if only one such ky is selected, then choosing that line as the next line to be acquired; otherwise

(B5) determining the number of previous acquisitions for each of the candidate ky lines;

(B6) selecting the ky line or lines with the fewest acquisitions;

(B7) if only one such ky is selected, then choosing that line as the next line to be acquired; otherwise

(B8) determining the average distance of previous acquisitions from the current position for each ky line;

(B9) selecting the ky line with the largest average distance;

(B10) if only one such ky line is selected, then choosing that line as the next line to be acquired; otherwise choosing any of these lines.

5. A method according to any preceding claim wherein, following each acquisition of ky data in the second phase of data collection, an image is created and displayed using acquired ky data spanning the smallest range of object positions.

6. A method according to claim 5 further comprising the step of allowing an operator, in us, to terminate image acquisition after displaying an image.

7. A method according to any preceding claim wherein the first pass acquisition order is chosen to initially collect data in the central portion of ky space, thereby allowing intermediate images to be created and displayed, albeit with a reduced spatial frequency bandwidth, before all ky lines have been acquired.

8. A method according to any preceding claim wherein the first pass acquisition order is chosen to initially collect data in a stepwise fashion across ky space, thereby allowing intermediate images to be created and displayed, albeit with a reduced resolution, before all ky lines have been acquired.

9. A magnetic resonance imaging heart monitor configured to use a method according to any preceding claim.

10. A method of generating a magnetic resonance image substantially as described herein with reference to and as illustrated by any appropriate combination of the accompanying drawings.

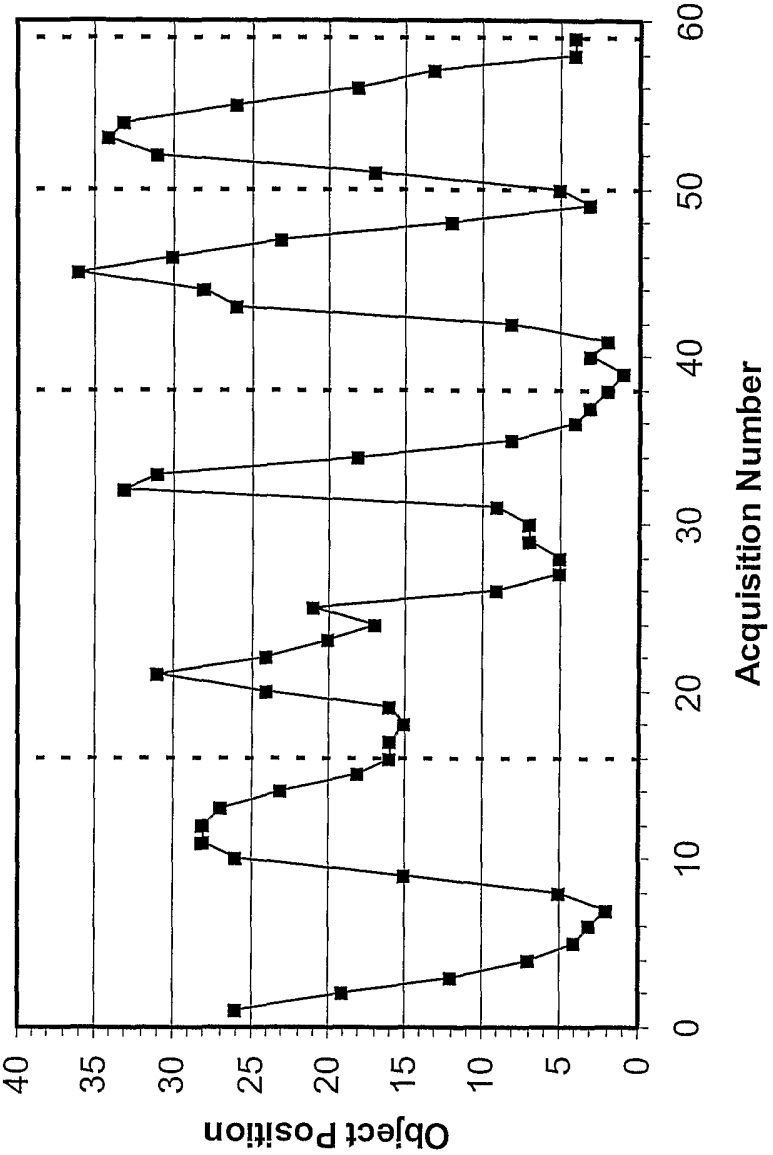

Object Position
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
Acquisition Number

Figure 1

Figure 2(a)

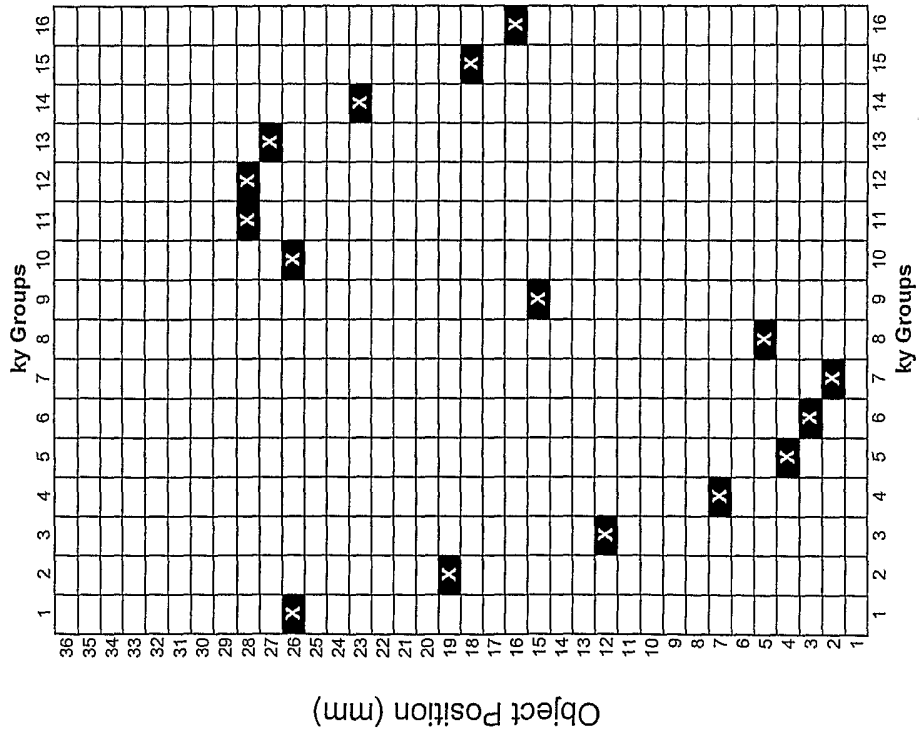


Figure 2(b)

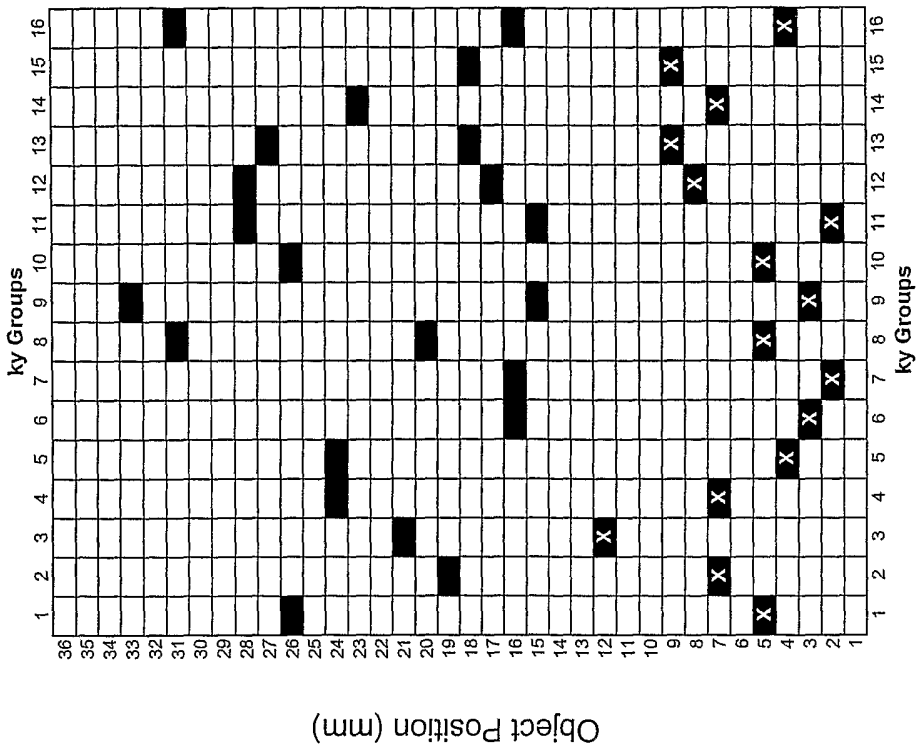


Figure 2(d)

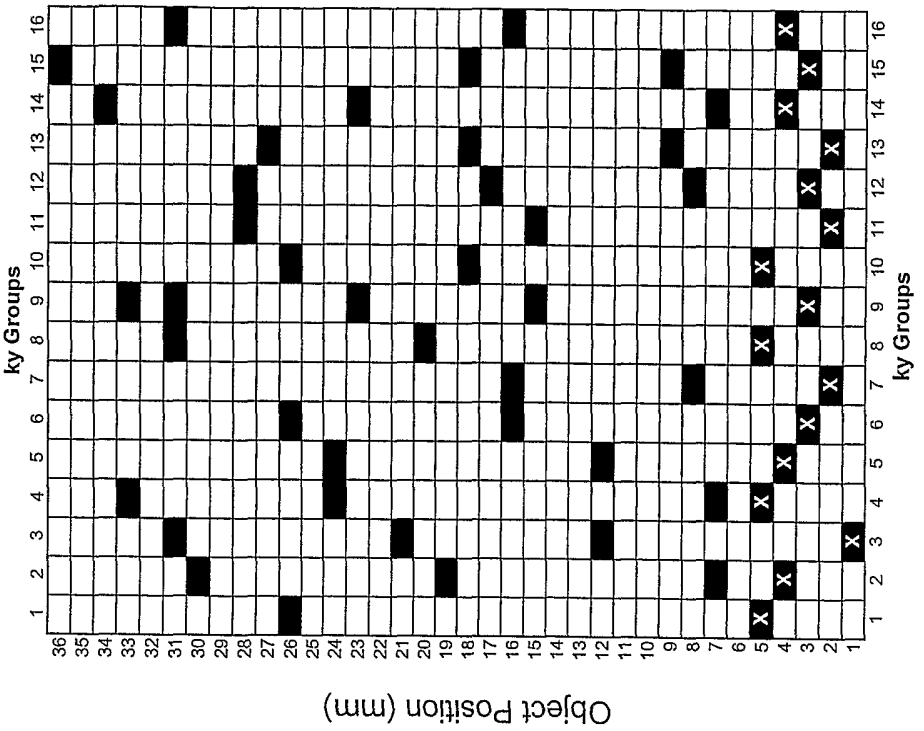
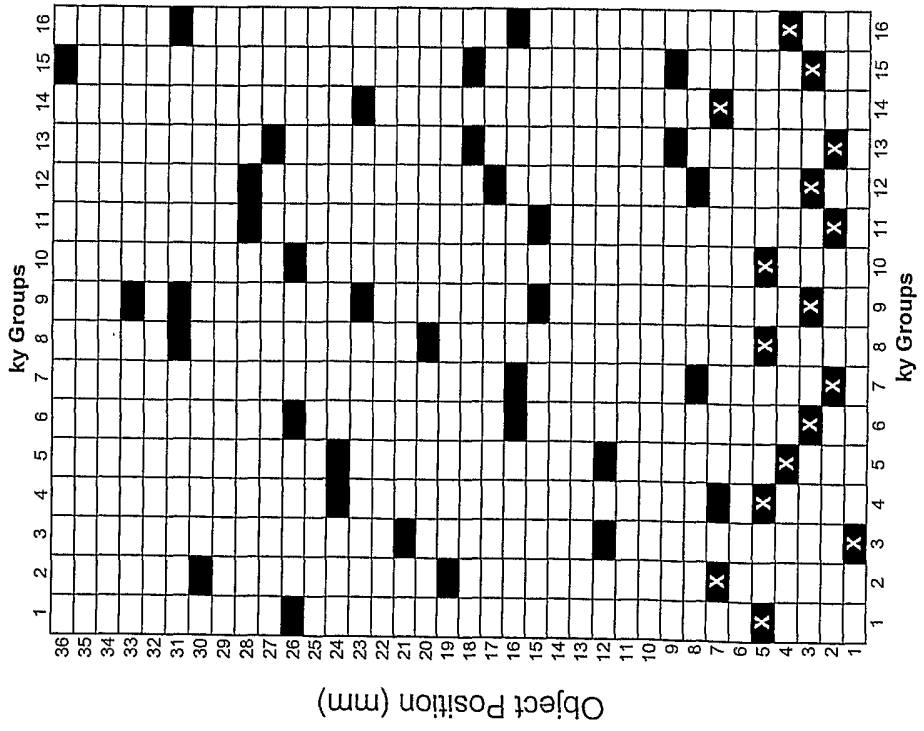


Figure 2(c)



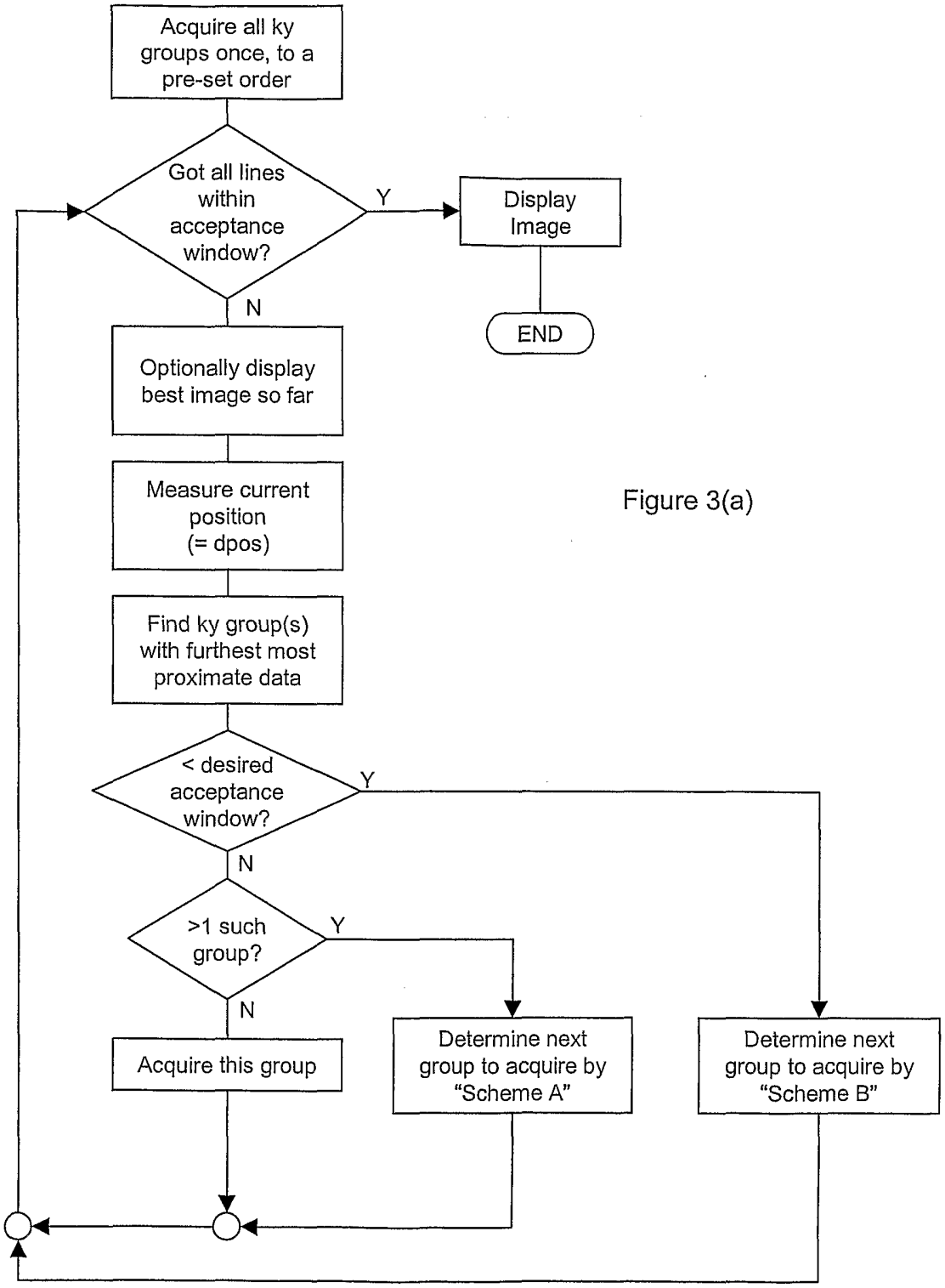

Acquire all ky groups once, to a pre-set order
Got all lines within acceptance window?
Y
Display Image
END
N
Optionally display best image so far
Measure current position (= dpos)
Find ky group(s) with furthest most proximate data
< desired acceptance window?
Y
N
>1 such group?
Y
N
Acquire this group
Determine next group to acquire by "Scheme A"
Determine next group to acquire by "Scheme B"

Figure 3(a)

Figure 3(b)

"Scheme B"

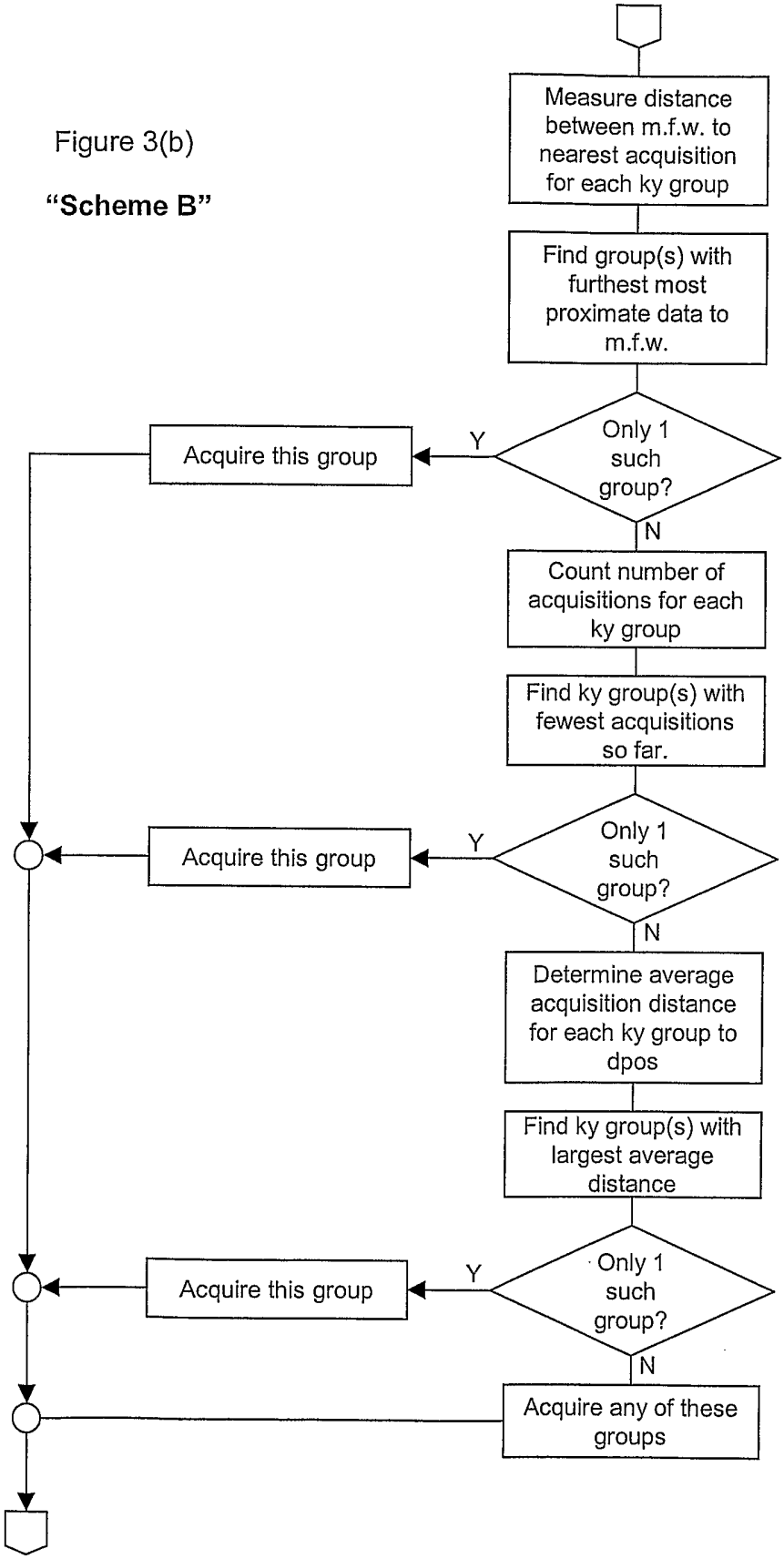
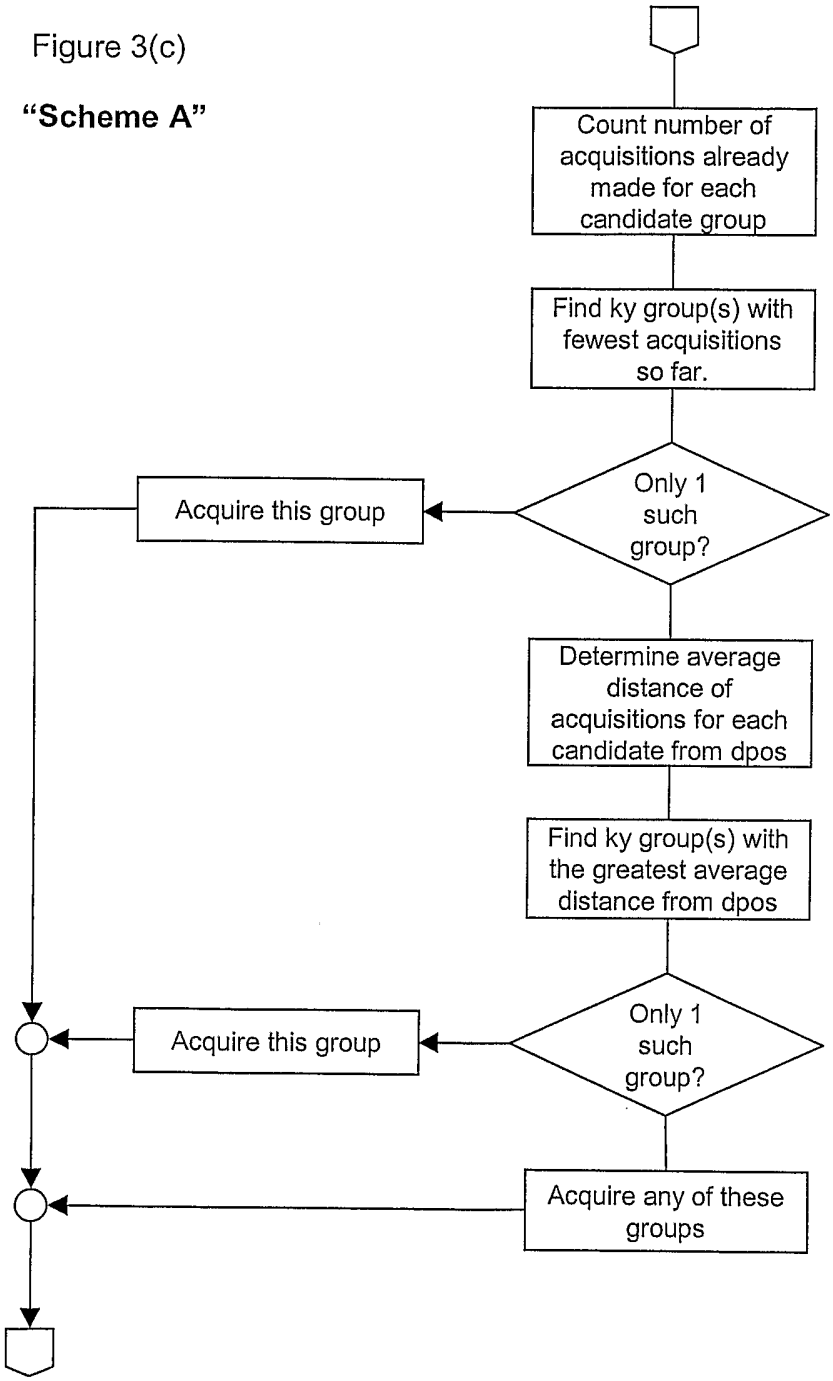


Figure 3(c)

"Scheme A"



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/001481

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R33/567

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)
G01R

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 practical, search terms used)
EPO-Internal, WPI Data, PAJ, COMPENDEX, INSPEC, MEDLINE, BIOSIS, EMBASE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JHOOTI P ET AL: "Phase ordering with automatic window selection (PAWS): a novel motion-resistant technique for 3D coronary imaging" MAGNETIC RESONANCE IN MEDICINE, ACADEMIC PRESS, DULUTH, MN, US, vol. 43, no. 3, March 2000 (2000-03), pages 470-480, XP002385286 ISSN: 0740-3194 cited in the application the whole document	1-9

-/--

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

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

"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	Date of mailing of the international search report
2 August 2006	31/08/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Skalla, J

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/001481

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SACHS T S ET AL: "THE DIMINISHING VARIANCE ALGORITHM FOR REAL-TIME REDUCTION OF MOTION ARTIFACTS IN MRI" MAGNETIC RESONANCE IN MEDICINE, ACADEMIC PRESS, DULUTH, MN, US, vol. 34, no. 3, 1 September 1995 (1995-09-01), pages 412-422, XP000527025 ISSN: 0740-3194 cited in the application * chapter "METHOD" *	1-9
A	NUVAL A ET AL: "AN IMPROVED REAL-TIME NAVIGATOR GATING ALGORITHM FOR REDUCING MOTION EFFECTS IN CORONARY MAGNETIC RESONANCE ANGIOGRAPHY" JOURNAL OF X-RAY SCIENCE AND TECHNOLOGY, AMSTERDAM, NL, vol. 11, no. 3, 2003, pages 115-123, XP009067858 ISSN: 0895-3996 figure 1	1-9
A	HACKENBROCH M ET AL: "3D motion adapted gating (3D MAG): a new navigator technique for accelerated acquisition of free breathing navigator gated 3D coronary MR-angiography." EUROPEAN RADIOLOGY, vol. 15, no. 8, 7 April 2005 (2005-04-07), pages 1598-1606, XP002393103 ISSN: 0938-7994 * section "3D motion adapted gating" *	1-9
A	US 2002/188191 A1 (KOLMOGOROV VLADIMIR N ET AL) 12 December 2002 (2002-12-12) paragraph [0029] - paragraph [0035]	1-9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2006/001481

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 10
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 10

Lack of clarity (Art. 6 PCT) because of vague reference to the description and accompanying drawings.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2006/001481

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002188191 A1	12-12-2002	NONE	