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(54) **AUTOMATIC QUANTIFICATION OF ASYMMETRY**

AUTOMATISCHE QUANTIFIZIERUNG VON ASYMMETRIEN

QUANTIFICATION AUTOMATIQUE D'ASYMÉTRIE

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Description

[0001] The present application relates to the diagnostic arts. It finds particular application in conjunction with functional images of the brain, including but not limited to positron emission tomography (PET) images and single photon emission computed tomography (SPECT) perfusion images. However, it will be appreciated that the described technique may also find application with other medical imaging device systems, other anatomical regions, or the like.

[0002] The human brain is mostly left-right symmetric, not only in terms of structure but also metabolism as measured by [18F] FDG PET imaging. Many subjects suffering from dementia also show symmetric impairment of brain metabolism. However, many dementia subjects exhibit asymmetric brain metabolism, in particular early in disease progression.

[0003] A determination of asymmetry in the brain has diagnostic value. With some forms of dementia, affected areas of the brain occur asymmetrically. For example, a high degree of asymmetry can be found in the very early stages of Alzheimer's disease. Measuring asymmetry can be used to detect or identify various types of dementia, including the early stages of Alzheimer's. Currently, a diagnostician manually compares sections of the brain or organ to determine how symmetric they are. This comparison calls for a great deal of skill and is difficult to quantize. Due to the subjective nature of the evaluations, comparing evaluations performed by different diagnosticians can be inaccurate. To further complicate a diagnosis, asymmetry in various regions of an organ, such as a brain, may be normal.

[0004] More specifically, one of the most effective ways of diagnosing the underlying disease causing dementia in its earlier stages is by performing an FDG-PET brain scan. Dementias like Alzheimer's disease cause typical patterns of hypometabolism in the brain. Unfortunately, accurate identification of these hypometabolic areas in FDG-PET brain scan images requires a great deal of skill, because these areas only show up as subtly different shades of gray. This is why reliable interpretation of FDG-PET brain scans is normally only performed by a highly experienced expert. In state-of-the-art analysis of FDG-PET images, asymmetry is often overlooked or not assessed, although it has diagnostic value. Slight asymmetries are hardly visible to the human eye.

[0005] Accordingly, there is a need for an automated quantification of asymmetry to aid a healthcare provider in a diagnosis.

[0006] The present application provides new and improved systems and methods, which overcome the above-referenced problems and others.

[0007] S MINOSHIMA et al in "A diagnostic approach in Alzheimer's disease using three-dimensional stereotactic surface projections of fluorine-18-FDG PET", Journal of Nuclear Medicine", vol. 36, no. 7, pp 1238-1248, report computing diagnostic indices to discriminate

Alzheimer disease patients from normal subjects.

[0008] The invention is according to appended claims.

[0009] In accordance with one aspect, an apparatus, for detecting asymmetry in an object, comprises a processor programmed to perform the steps of comparing corresponding voxels on opposite sides of an image of the object. Based on the comparing, the apparatus generates at least one of an asymmetry map and an asymmetry index.

[0010] In accordance with another aspect, a method for detecting asymmetry comprises comparing pairs of corresponding pixels on opposite sides of an image of an object, and based on the comparing, generating at least one of an asymmetry map and an asymmetry index.

[0011] One advantage is that asymmetry can be more easily detected.

[0012] Another advantage is that asymmetry can be quantified.

[0013] Another advantage resides in detecting Alzheimer's disease at a very early stage.

[0014] Still further advantages of the subject innovation will be appreciated by those of ordinary skill in the art upon reading and understand the following detailed description.

[0015] The innovation 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 various aspects and are not to be construed as limiting the invention.

FIGURE 1 illustrates a system that facilitates displaying an asymmetry map by comparing an acquired image to an existing template, in accordance with various aspects described herein.

FIGURE 2 illustrates an asymmetry map calculation sequence that displays an asymmetry map and a corresponding asymmetry index, which eliminates the need for manual comparison of images to determine asymmetry or abnormalities.

FIGURE 3 illustrates the use of a mask in calculation of an asymmetry index.

FIGURE 4 illustrates the use of a z-score in calculation of an asymmetry index.

FIGURE 5 illustrates an example asymmetry map.

FIGURE 6 illustrates another example asymmetry map.

[0016] FIGURE 1 illustrates a system **100** that calculates an asymmetry index. The system **100** includes one or more processors **102** coupled to a functional scanner **104**, such as a PET or other nuclear medicine scanner, and a scanner memory **105**. In one embodiment, a processor memory **106** stores, and the processor **102** executes, computer-executable instructions for performing the various functions, methods, techniques, procedures, etc., described herein. The computer-executable instructions are stored as modules in the processor memory **106**. In another embodiment, a series of engines, mod-

ules, hardware components or the like implement the below described functions. The system further includes a display **108** that presents information to a user.

[0017] The scanner **104** scans an object, such as a brain to generate functional image data, preferably in lists made with the received data time stamped. The image data is stored in the scanner memory **105**.

[0018] A reconstruction unit **110** coupled to the scanner memory **105** accesses the image data and reconstructs the data into a three-dimensional image that represents the scanned object. In one embodiment, the image is reconstructed from PET using time-of-flight (TOF) information such that the three-dimensional image represents a distribution of a radiopharmaceutical in the brain or other organ. For example, if the radiopharmaceutical includes glucose, it is taken up into active regions of the brain with higher metabolic activity and little or no glucose is taken up into metabolically impaired or damaged regions. The impaired regions show up darker in the three-dimensional image.

[0019] A normalization module **112**, in the form of hardware or a registration algorithm or instructions from the processor memory **106**, fits the three-dimensional image to a standard brain atlas or template, e.g. a stereotactic normalization.

[0020] A projection module **114**, in the form of a dedicated hardware or processor programmed to perform a projection algorithm or instructions, projects or maps the three-dimensional image of the brain, particularly the radiopharmaceutical distribution indicative of, up onto the brain surface. More specifically to the illustrated embodiments, the projection module maps the three dimensional image onto eight stereotactic surface projections, including left lateral, right lateral, superior, inferior, anterior, posterior left medial, and right medial. If the brain is symmetric, opposite sides of the brain, particularly opposite projection images, would be mirror image symmetric, i.e., corresponding pixels of the pair of projection images of opposite sides of the brain would be the same. The projection views are saved in the memory **106** and are selectively displayed on the display **108**.

[0021] Lateral and medial projections of the left and right brain hemispheres have several advantages over volume images. This visual representation is easier to interpret. Surface projections reduce inter-subject as well as intra-subject variability caused by individual differences in cortical structure. Surface projections are therefore well suited to capture functional asymmetry (being more robust to structural asymmetry).

[0022] A pixel computation module **116** in the form of dedicated hardware or a processor programmed to perform a pixel computation algorithm or computer instructions, identifies corresponding, e.g. mirror image symmetric, pixels x_i in each half of the brain e.g. the left and right sides. The pixel computation module **116** compares each pair of corresponding surface pixels to determine relative asymmetry. When a plurality of the stereotactic surface projections is used in the comparing, the dupli-

cative information in two or more of the projection images is ignored, and the pixel computation module **116** does not assess duplicative values twice. Alternately, duplicative data can be eliminated during the mapping or projecting.

[0023] An asymmetry determination module **118**, in the form of hardware or a programmed processor, computes an asymmetry map, FIGURE 5, or an asymmetry index value from the differences between corresponding pixels generated by the pixel computation module **116**. In one embodiment, the system computes two asymmetry maps, including a medial plot and a lateral plot with intensity variations indicating relative degrees of asymmetry. In another embodiment, the system computes eight surface projections that also show intensity variations indicative of relative degrees of asymmetry.

[0024] In another embodiment, the asymmetry determination module **118** generates an asymmetry index. The asymmetry index is a numerical value that represents the relative asymmetry of the examined brain, as a whole or selected portions thereof, compared to a normal brain. In one embodiment, a scanned object that is relatively symmetric has a low asymmetry index. Whereas, a scanned object that is relatively asymmetric has a higher asymmetry index, e.g. number of standard deviations from normal. By providing the asymmetry index as a scalar representation, a user can quickly and efficiently determine the level of commonality between the scanned object and normal. A display module **120** converts outputs the asymmetry information (e.g. asymmetry map or index) to an appropriate format for display on the display **108**.

[0025] In another embodiment, the asymmetry determination module **118** outputs the asymmetry index to a clinical decision support system (CDSS) **122**. The CDSS **122** can take into account a variety of factors (e.g. age, other test results, etc.) to provide a more complete and accurate diagnosis or suggested treatment plan. The CDSS **122** is operatively connected to a hospital database **124**, which acts as a repository for patient information. The information may include, but is not limited to information relating a specific patient for whom the asymmetry index corresponds. For example, the hospital database **124** can include information relating to the patient's age, demographics, prior medical history, etc. The CDSS **122** can retrieve information (e.g. results of other tests of a patient) from the hospital database **124**, and use the retrieved information in conjunction with the asymmetry index to generate probabilities of various diagnoses or proposed courses of treatment. The CDSS **122** can also mitigate the need for a visual interpretation of the asymmetry by a physician, since the asymmetry index can be automatically machine determined. The system can aid less-experienced physicians in obtaining an accurate diagnosis. The CDSS **122** can output the generated results to the CDSS display **126** for presentation.

[0026] FIGURE 2 illustrates a method **200** for calculat-

ing asymmetry information, in accordance with various features. While the method is described as a series of acts, it will be understood that not all acts may be required to achieve the described goals and/or outcomes, and that some acts may, in accordance with certain aspects, be performed in an order different than the specific orders described. The acts can be performed by suitably programmed processors, such as **102** and **110**.

[0027] At **210**, an object, e.g. brain, is scanned to generate image data associated with the object. For metabolic brain imaging, PET imaging is advantageous, and perfusion SPECT imaging is also useful. At **220**, the image data is reconstructed to form a three-dimensional image of the scanned object. At **230**, a stereotactic normalization is performed on each voxel of the reconstructed three-dimensional image. The voxels of the reconstructed three-dimensional image are spatially transformed to standard coordinates, such as a symmetrical brain atlas or template, e.g. using a non-affine image registration. In this manner, the size and shape of the brain is standardized for all patients. At **240**, the three-dimensional image is mapped, e.g. projected, to a series of two-dimensional images projected onto the brain surface. The two-dimensional images can comprise a multitude of views of each hemisphere, including left lateral, right lateral, superior, inferior, anterior, posterior, left medial, and right medial, among others.

[0028] Various ways of computing the asymmetry from the corresponding pixel pairs are described below. At **260**, a brain surface asymmetry map is created from the differences or relative asymmetry between the corresponding left-right pixel pairs. For example, the surface asymmetry map shows relative asymmetry by color/grey scale coding of a medial and lateral projection of one side of the brain (the other side would look the same but mirror image reversed). Relative differences in the corresponding pixel pairs are represented by color or grey scale shading differences within the asymmetry map. For example, lighter shades can indicate surface portions that are more asymmetric. At **270**, projections of the surface asymmetry map, such as the medial and lateral projections, are displayed to a user on display **108** or any other suitable display device.

[0029] At **280**, an overall asymmetry value, such as a scalar asymmetry index, is calculated. The asymmetry index represents a level of asymmetry of the overall or some selected portion of the brain. The asymmetry index can be represented as a scalar number that summarizes the level of asymmetry over the scanned object. In one embodiment, the asymmetry index is computed using a mean of the asymmetry level of each pixel on the map. For example, the asymmetry of each pixel can be ranked on a scale from 1 to 10. The mean asymmetry level of the pixels on the asymmetry map can be subsequently computed. Similarly, the system and method can compute an asymmetry index that represents a median asymmetry of the pixels in a similar way. In another embodiment, the overall asymmetry measure is a vector of mul-

iple scalar asymmetry indices, each index derived with a different method at **250**.

[0030] The calculated asymmetry index, or a vector of multiple scalar asymmetry indices, is optionally sent to a clinical decision support system (CDSS) to assist with a diagnosis. The CDSS can use the asymmetry index in conjunction with other image-based information (e.g. volume of hypometabolism) or non-image-based information (age, lab tests, etc.) to provide information relating to the patient. Decision support software aims to assist in the interpretation of the images to the point where accurate diagnoses can be made by less experienced physicians. This could make diagnostic services for the early diagnosis of dementia much more widely available. The automatic assessment of brain asymmetry is a useful marker of brain non-normality in general, and early dementia in particular.

[0031] As stated above, the system **100** includes the processor **104** that executes, and the processor memory **106**, which stores, computer-executable instructions (e.g., routines, programs, algorithms, software code, etc.) for performing the various functions, methods, procedures, etc., described herein. Additionally, "module," as used herein, denotes a set of computer-executable instructions, software code, program, routine, ASICs, array processors and other hardware components, or the like, as will be understood by those of skill in the art.

[0032] The memory may be a computer-readable medium on which a control program is stored, such as a disk, hard drive, or the like. Common forms of non-transitory computer-readable media include, for example, floppy disks, flexible disks, hard disks, magnetic tape, or any other magnetic storage medium, CD-ROM, DVD, or any other optical medium, RAM, ROM, PROM, EPROM, FLASH-EPROM, variants thereof, other memory chip or cartridge, or any other tangible medium from which the processor can read and execute. In this context, the systems described herein may be implemented on or as one or more general purpose computers, special purpose computer(s), a programmed microprocessor or microcontroller and peripheral integrated circuit elements, an ASIC or other integrated circuit, a digital signal processor, a hardwired electronic or logic circuit such as a discrete element circuit, a programmable logic device such as a PLD, PLA, FPGA, Graphical card CPU (GPU), or PAL, or the like.

[0033] In one embodiment, pixels of the two-dimensional images of the object are masked before computing the asymmetry. An object may be expected to be asymmetric in some areas, while symmetric in others. Some portions are asymmetric in normal brains. A mask is applied at **300** to exclude pixels from the calculation which are expected, under normal circumstances, to exhibit asymmetry. Alternatively, the applied mask excludes pixels with low reliability. For example, the mask can exclude pixels with a standard deviation of the asymmetry index above a certain threshold in a group of normal brains stored in a normal asymmetry database **302**.

[0034] With reference to FIGURE 3, the asymmetry at each corresponding pixel pair x_{Li} , x_{Ri} in the left and right hemispheres is calculated. In one embodiment, at **310** the absolute difference (D_{abs}) for each pixel pair is calculated by determining the absolute value of the difference between the corresponding left and right pixels (x_{Li} , x_{Ri}), i.e., $D_{abs}(x_i) = |x_{Li} - x_{Ri}|$. In another embodiment, a percent difference D_{per} is determined at **320**, i.e. $D_{per}(x_i) = 2 * D_{abs}(x_i) / (x_{Li} + x_{Ri})$. In another embodiment, at **330** the method determines a ratio $R(x_i)$ of the corresponding left and right pixels x_{Li} , x_{Ri} , i.e.:

$$R(x_i) = (x_{Li} / x_{Ri}) - 1.$$

[0035] The absolute difference, the relative (percent) difference, or the ratio can be used in step **260** to calculate the asymmetry map. The grey scale or color values are set in accordance with the magnitude of the difference, percent difference or ratio. To calculate the aggregate asymmetry index in step **280**, the absolute values of asymmetry pixel values are considered (i.e. D_{abs} , $|D_{per}|$, $|R|$). In one embodiment, a statistical property, such as a mean or median or a percentile of the asymmetry values, is computed. In another embodiment, a threshold is chosen, e.g. a percent difference of 10% for D_{per} and the number of pixels with D_{per} greater than the threshold value is counted.

[0036] FIGURE 4 illustrates another calculation of asymmetry information by mapping a z-score before computing an asymmetry index. Before computing an asymmetry index, the method computes a z-score for each corresponding left-right pixel pair on the two-dimensional map. For example, the following formula can be employed to calculate the z-score for each pixel x_i : $z(x_i) = (a(x_i) - \text{mean}_a(x_i)) / \text{std}_a(x_i)$, where $a(x_i)$ represents the asymmetry measure, such as difference, percent difference, ratio, or the like, at the pixel x_i . $\text{Mean}_a()$ and $\text{std}_a()$ represent mean and standard deviation of the asymmetry measure $a()$, previously computed on a database of normal brain images. At **260**, the asymmetry map is generated using the z-score to set the grey scale or color value at the corresponding pixel. At **280**, the z-score is used to compute the asymmetry index.

[0037] FIGURE 5 illustrates an example asymmetry map generated by the system **100** and the method **200**. The map shows a lateral and medial plot of relative intensity differences. Pixels are shown in different shades based on asymmetry values of the corresponding voxels. Bright pixels denote pixels where image intensity is larger in the right hemisphere; dark pixels are associated with higher image intensity in left hemisphere.

[0038] FIGURE 6 illustrates an example asymmetry map generated by the system **100** and the method **200**. The map shows two-dimensional images, including left lateral, right lateral, superior, inferior, anterior, posterior, left medial, and right medial, but is not limited to such

images. Pixels are shown in different shades based on asymmetry values of the corresponding voxels. Bright pixels denote pixels where image asymmetry is larger; dark pixels are associated with more symmetric pixels.

[0039] The innovation has been described with reference to several embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the innovation be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims.

Claims

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1. An apparatus (100) for detecting functional asymmetry in an object, the apparatus comprising: a processor (102) programmed to perform the steps of:

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fitting a three-dimensional functional image of the object to a preselected standard shape of the object,

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projecting the fitted three-dimensional image of the object onto a two-dimensional surface image,

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comparing pairs of corresponding pixels on the two-dimensional surface, the pairs of pixels corresponding to voxels on opposite sides of the three-dimensional functional image of the object;

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based on the comparing, generating at least one of an asymmetry map and an asymmetry index.

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2. The apparatus according to claim 1, wherein the object is a brain and the processor is further programmed to: fit a three-dimensional functional image of the brain to a standard brain atlas.

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3. The apparatus according to claim 2, wherein the processor is further programmed to: compute a z-score for the corresponding pixel pairs on opposite sides of the surface image according to the following formula:

50

$$z(x_i) = (a(x_i) - \text{mean}(x_i)) / \text{std}(x_i),$$

55

wherein $a(x_i)$ represents an asymmetry measure at the corresponding pixel pair x_i , $\text{mean}(x_i)$ represents the mean asymmetry measure for the pixel pair x_i , and $\text{std}(x_i)$ represents the standard deviation asymmetry measure for the pixel pair x_i , wherein the processor calculates the $\text{mean}(x_i)$ and the $\text{std}(x_i)$ based on at least one normal brain map.

4. The apparatus according to any one of claims 1-3, wherein the processor is further programmed to perform at least one of:

compute an absolute difference between corresponding pixels on opposite sides of the surface image for use in the calculation of the asymmetry map or the asymmetry index;
 compute a relative difference for use in the calculation of the asymmetry map or the asymmetry;
 compute a ratio between amplitudes of corresponding pixel pairs on opposite sides of the surface image for use in the calculation of the asymmetry map or asymmetry index.

5. The apparatus according to any one of claims 1-4, wherein the processor is further programmed to: compute the asymmetry index based on how much the pixels in each corresponding pixel pair differ and a number of pixel pairs which differ by more than a threshold or percentage.

6. The apparatus according to any one of claims 3-5, wherein the processor is further programmed to: mask pixels of the surface image which are asymmetric in normal brains, wherein the masking is performed after the projecting and before the comparing step.

7. The apparatus according to any one of claims 1-6, further including: a clinical decision support system (122) which receives and uses the at least one of the asymmetry map and asymmetry index.

8. A method for detecting functional asymmetry, the method comprising:

fitting (230) a three-dimensional functional image of the object to a preselected standard shape of the object,
 projecting (240) the fitted three-dimensional image of the object onto a two-dimensional surface image,
 comparing pairs of corresponding pixels on the two-dimensional surface, the pairs of pixels corresponding to pixels on opposite sides of the three-dimensional functional image of the object;
 based on the comparing, generating at least one of an asymmetry map and an asymmetry index.

9. The method according to claim 8, further including: before the comparing step, masking pixels of the surface image which are asymmetric in normal objects or for whom asymmetry calculations are unreliable.

10. The method according to any one of claims 8-9, wherein the comparing step includes determining at least one of:

an absolute difference between pixels of each corresponding pixel pair,
 a relative difference between pixels of each corresponding pixel pair, and
 a ratio between pixels of each corresponding pixel pair.

11. The method according to any one of claims 8-10, wherein the comparing step includes: computing a z-score for each pixel pair on the surface image according to the following formula:

$$z(x_i) = (a(x_i) - \text{mean}(x_i)) / \text{std}(x_i),$$

wherein $a(x_i)$ represents a difference, relative difference, or ratio asymmetry measure at the corresponding pixel pair x_i , $\text{mean}(x_i)$ represents a mean asymmetry measure for the pixel pair x_i relative to normal data, and $\text{std}(x_i)$ represents a standard deviation asymmetry measure for the pixel pair x_i relative to normal data.

12. The method according to any one of claims 8-11, wherein generating the asymmetry index includes: determining a relative number or percent of the pixel pairs which were determined to deviate in the comparing step.

13. The method according to any one of claims 8-12, wherein generating the asymmetry map includes: adjusting color or grey scale on a two-dimensional image in accordance with deviations in values of the pixels in each corresponding pixel pair.

14. A computer readable medium carrying software which controls one or more processors to perform the method according to any one of claims 8-13.

15. A system (100) for detecting brain maladies the system comprising:

a database (124) which stores patient medical and demographic data;
 the apparatus according to any one of claims 2-7; and
 a clinical decision support system (CDSS) (122) that generates at least one of a proposed diagnosis or treatment plan from the asymmetry index or map and information retrieved from the hospital database (124).

Patentansprüche

1. Gerät (100) zum Erkennen funktioneller Asymmetrie in einem Objekt, wobei das Gerät Folgendes umfasst:
einen Prozessor (102), der programmiert ist, um die folgenden Schritte durchzuführen:

Anpassen eines dreidimensionalen funktionellen Bilds des Objekts an eine vorausgewählte Standardform des Objekts,
Projizieren des angepassten dreidimensionalen Bilds des Objekts auf ein zweidimensionales Oberflächenbild,
Vergleichen von Paaren entsprechender Pixel auf der zweidimensionalen Oberfläche, wobei die Paare von Pixeln Voxeln auf gegenüberliegenden Seiten des dreidimensionalen funktionellen Bilds des Objekts entsprechen;
Erzeugen von mindestens einem von einer Asymmetriekarte und einem Asymmetrieindex basierend auf dem Vergleich.

2. Gerät nach Anspruch 1, wobei das Objekt ein Gehirn ist und der Prozessor ferner programmiert ist zum:
Anpassen eines dreidimensionalen funktionellen Bilds des Gehirns an einen Standardgehirnatlas.

3. Gerät nach Anspruch 2, wobei der Prozessor ferner programmiert ist zum:
Berechnen einer z-Punktzahl für die entsprechenden Pixelpaare auf gegenüberliegenden Seiten des Oberflächenbilds nach der folgenden Formel:

$$z(x_i) = (a(x_i) - \text{mean}(x_i)) / \text{std}(x_i),$$

wobei $a(x_i)$ ein Asymmetriemaß bei dem entsprechenden Pixelpaar x_i darstellt, $\text{mean}(x_i)$ das mittlere Asymmetriemaß für das Pixelpaar x_i darstellt und $\text{std}(x_i)$ das Standardabweichungs-Asymmetriemaß für das Pixelpaar x_i darstellt, wobei der Prozessor $\text{mean}(x_i)$ und $\text{std}(x_i)$ basierend auf mindestens einer normalen Gehirnkarte berechnet.

4. Gerät nach einem der Ansprüche 1 bis 3, wobei der Prozessor ferner programmiert ist, um mindestens eines von Folgendem durchzuführen:

Berechnen einer absoluten Differenz zwischen entsprechenden Pixeln auf gegenüberliegenden Seiten des Oberflächenbilds zur Verwendung in der Berechnung der Asymmetriekarte oder des Asymmetrieindex;
Berechnen einer relativen Differenz zur Verwendung in der Berechnung der Asymmetriekarte oder der Asymmetrie;

Berechnen eines Verhältnisses zwischen Amplituden von entsprechenden Pixelpaaren auf gegenüberliegenden Seiten des Oberflächenbilds zur Verwendung in der Berechnung der Asymmetriekarte oder des Asymmetrieindex.

5. Gerät nach einem der Ansprüche 1 bis 4, wobei der Prozessor ferner programmiert ist zum:

Berechnen des Asymmetrieindex basierend darauf, wie stark sich die Pixel in jedem entsprechenden Pixelpaar unterscheiden, und auf einer Anzahl von Pixelpaaren, die sich um mehr als einen Schwellenwert oder Prozentsatz unterscheiden.

6. Gerät nach einem der Ansprüche 3 bis 5, wobei der Prozessor ferner programmiert ist zum:

Maskieren von Pixeln des Oberflächenbilds, die in normalen Gehirnen asymmetrisch sind, wobei das Maskieren nach dem Schritt des Projizierens und vor dem Schritt des Vergleichens durchgeführt wird.

7. Gerät nach einem der Ansprüche 1 bis 6, ferner umfassend:

ein klinisches Entscheidungsunterstützungssystem (122), das mindestens eines von der Asymmetriekarte und dem Asymmetrieindex empfängt und nutzt.

8. Verfahren zum Erkennen funktioneller Asymmetrie, wobei das Verfahren Folgendes umfasst:

Anpassen (230) eines dreidimensionalen funktionellen Bilds des Objekts an eine vorausgewählte Standardform des Objekts,
Projizieren (240) des angepassten dreidimensionalen Bilds des Objekts auf ein zweidimensionales Oberflächenbild,
Vergleichen von Paaren entsprechender Pixel auf der zweidimensionalen Oberfläche, wobei die Paare von Pixeln auf gegenüberliegenden Seiten des dreidimensionalen funktionellen Bilds des Objekts entsprechen;

Erzeugen von mindestens einem von einer Asymmetriekarte und einem Asymmetrieindex basierend auf dem Vergleich.

9. Verfahren nach Anspruch 8, ferner umfassend:
vor dem Schritt des Vergleichens, Maskieren von Pixeln des Oberflächenbilds, die in normalen Objekten asymmetrisch sind oder für die Asymmetrieberechnungen unzuverlässig sind.

10. Verfahren nach einem der Ansprüche 8 bis 9, wobei der Schritt des Vergleichens das Bestimmen von mindestens einem von Folgendem umfasst:

einer absoluten Differenz zwischen Pixeln von jedem entsprechenden Pixelpaar,

einer relativen Differenz zwischen Pixeln von jedem entsprechenden Pixelpaar, und eines Verhältnisses zwischen Pixeln von jedem entsprechenden Pixelpaar.

11. Verfahren nach einem der Ansprüche 8 bis 10, wobei der Schritt des Vergleichens Folgendes umfasst: Berechnen einer z-Punktzahl für jedes Pixelpaar auf dem Oberflächenbild nach der folgenden Formel:

$$z(x_i) = (a(x_i) - \text{mean}(x_i)) / \text{std}(x_i),$$

wobei $a(x_i)$ ein Differenz-, relatives Differenz- oder Verhältnis-Asymmetriemaß bei dem entsprechenden Pixelpaar x ; darstellt, $\text{mean}(x_i)$ ein mittleres Asymmetriemaß für das Pixelpaar x ; relativ zu Normaldaten darstellt und $\text{std}(x_i)$ ein Standardabweichungs-Asymmetriemaß für das Pixelpaar x ; relativ zu Normaldaten darstellt.

12. Verfahren nach einem der Ansprüche 8 bis 11, wobei das Erzeugen des Asymmetrieindex Folgendes umfasst: Bestimmen einer relativen Anzahl oder eines Prozentsatzes von Pixelpaaren, für die beim Vergleichsschritt eine Abweichung ermittelt wurde.
13. Verfahren nach einem der Ansprüche 8 bis 12, wobei das Erzeugen der Asymmetriekarte Folgendes umfasst: Anpassen der Farb- oder Grauskala auf einem zweidimensionalen Bild in Übereinstimmung mit Abweichungen in Werten der Pixel in jedem entsprechenden Pixelpaar.
14. Computerlesbares Medium mit Software, die einen oder mehrere Prozessoren steuert, um das Verfahren nach einem der Ansprüche 8 bis 13 durchzuführen.
15. System (100) zum Erkennen von Gehirnerkrankungen, wobei das System Folgendes umfasst:

eine Datenbank (124), in der medizinische und demographische Daten der Patienten gespeichert sind;
das Gerät nach einem der Ansprüche 2 bis 7; und
ein klinisches Entscheidungsunterstützungssystem (CDSS) (122), das anhand des Asymmetrieindex oder der Asymmetriekarte und der aus der Krankenhausdatenbank (124) abgerufenen Informationen mindestens eines von einer vorgeschlagenen Diagnose oder einen Behandlungsplan erzeugt.

Revendications

1. Appareil (100) pour détecter une asymétrie fonctionnelle dans un objet, l'appareil comprenant :
un processeur (102) programmé pour effectuer les étapes consistant à :

adapter une image fonctionnelle tridimensionnelle de l'objet à une forme standard présélectionnée de l'objet,
projeter l'image tridimensionnelle adaptée de l'objet sur une image de surface bidimensionnelle,
comparer des paires de pixels correspondantes sur la surface bidimensionnelle, les paires de pixels correspondant à des voxels sur des côtés opposés de l'image fonctionnelle tridimensionnelle de l'objet ;
sur la base de la comparaison, générer au moins l'un(e) d'une carte d'asymétrie et d'un index d'asymétrie.

2. Appareil selon la revendication 1, dans lequel l'objet est un cerveau et le processeur est en outre programmé pour :
adapter une image fonctionnelle tridimensionnelle du cerveau à un atlas de cerveau standard.

3. Appareil selon la revendication 2, dans lequel le processeur est en outre programmé pour :
calculer un score z pour les paires de pixels correspondantes sur les côtés opposés de l'image de surface selon la formule suivante :

$$z(x_i) = (a(x_i) - \text{moyenne}(x_i)) / \text{std}(x_i),$$

dans lequel $a(x_i)$ représente une mesure d'asymétrie dans la paire de pixels correspondantes x_i , $\text{moyenne}(x_i)$ représente la mesure d'asymétrie moyenne pour la paire de pixels x_i et $\text{std}(x_i)$ représente la mesure d'asymétrie d'écart-type pour la paire de pixels x_i , dans lequel le processeur calcule la moyenne(x_i) et le $\text{std}(x_i)$ sur la base d'au moins une carte de cerveau normale.

4. Appareil selon l'une quelconque des revendications 1 à 3, dans lequel le processeur est en outre programmé pour effectuer au moins l'une des étapes consistant à :

calculer une différence absolue entre des pixels correspondants sur des côtés opposés de l'image de surface pour une utilisation dans le calcul de la carte d'asymétrie ou de l'index d'asymétrie ;
calculer une différence relative pour une utilisation

- tion dans le calcul de la carte d'asymétrie ou de l'asymétrie ;
calculer un rapport entre les amplitudes de paires de pixels correspondantes sur les côtés opposés de l'image de surface pour une utilisation dans le calcul de la carte d'asymétrie ou de l'index d'asymétrie.
5. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel le processeur est en outre programmé pour :
calculer l'index d'asymétrie sur la base de la quantité des pixels de chaque paire de pixels correspondante qui diffère et sur le nombre de paires de pixels qui diffère de plus d'un seuil ou d'un pourcentage.
6. Appareil selon l'une quelconque des revendications 3 à 5, dans lequel le processeur est en outre programmé pour :
masquer les pixels de l'image de surface qui sont asymétriques dans des cerveaux normaux, dans lequel le masquage est effectué après l'étape de projection et avant l'étape de comparaison.
7. Appareil selon l'une quelconque des revendications 1 à 6, incluant en outre :
un système de support de décision clinique (122) qui reçoit et utilise la ou le au moins un(e) de la carte d'asymétrie et de l'index d'asymétrie.
8. Procédé de détection d'une asymétrie fonctionnelle, le procédé comprenant :
l'adaptation (230) d'une image fonctionnelle tridimensionnelle de l'objet à une forme standard présélectionnée de l'objet,
la projection (240) de l'image tridimensionnelle adaptée de l'objet sur une image de surface bidimensionnelle,
la comparaison de paires de pixels correspondantes sur la surface bidimensionnelle, les paires de pixels correspondant à des pixels sur les côtés opposés de l'image fonctionnelle tridimensionnelle de l'objet ;
sur la base de la comparaison, la génération d'au moins l'un(e) d'une carte d'asymétrie et d'un index d'asymétrie.
9. Procédé selon la revendication 8, incluant en outre :
avant l'étape de comparaison, le masquage de pixels de l'image de surface qui sont asymétriques dans des objets normaux ou pour lesquels des calculs d'asymétrie ne sont pas fiables.
10. Procédé selon l'une quelconque des revendications 8 à 9, dans lequel l'étape de comparaison inclut la détermination d'au moins l'une des situations suivantes :
- une différence absolue entre les pixels de chaque paire de pixels correspondante,
une différence relative entre les pixels de chaque paire de pixels correspondante, et
un rapport entre les pixels de chaque paire de pixels correspondante.
11. Procédé selon l'une quelconque des revendications 8 à 10, dans lequel l'étape de comparaison inclut :
le calcul d'un score z pour chaque paire de pixels sur l'image de surface selon la formule suivante :
- $$z(x_i) = (a(x_i) - \text{moyenne}(x_i)) / \text{std}(x_i),$$
- dans lequel $a(x_i)$ représente une mesure d'asymétrie de différence, de différence relative ou de rapport dans la paire de pixels correspondante x_i , $\text{moyenne}(x_i)$ représente une mesure d'asymétrie moyenne pour la paire de pixels x_i relativement à des données normales et $\text{std}(x_i)$ représente une mesure d'asymétrie d'écart-type pour la paire de pixels x_i relativement à des données normales.
12. Procédé selon l'une quelconque des revendications 8 à 11, dans lequel la génération de l'index d'asymétrie inclut :
la détermination d'un nombre ou d'un pourcentage relatif des paires de pixels qui ont été déterminées pour dévier dans l'étape de comparaison.
13. Procédé selon l'une quelconque des revendications 8 à 12, dans lequel la génération de la carte d'asymétrie inclut :
l'ajustement d'une échelle de couleur ou de gris sur une image bidimensionnelle selon des écarts dans les valeurs des pixels de chaque paire de pixels correspondante.
14. Support lisible par ordinateur portant un logiciel qui commande à un ou plusieurs processeurs d'effectuer le procédé selon l'une quelconque des revendications 8 à 13.
15. Système (100) pour détecter des maladies cérébrales, le système comprenant :
une base de données (124) qui stocke des données médicales et démographiques de patients ;
l'appareil selon l'une quelconque des revendications 2 à 7 ; et
un système de support de décision clinique (CDSS) (122) qui génère au moins l'un d'un diagnostic ou d'un plan de traitement proposé à partir de l'index ou de la carte d'asymétrie et d'informations récupérées dans la base de don-

nées (124) de l'hôpital.

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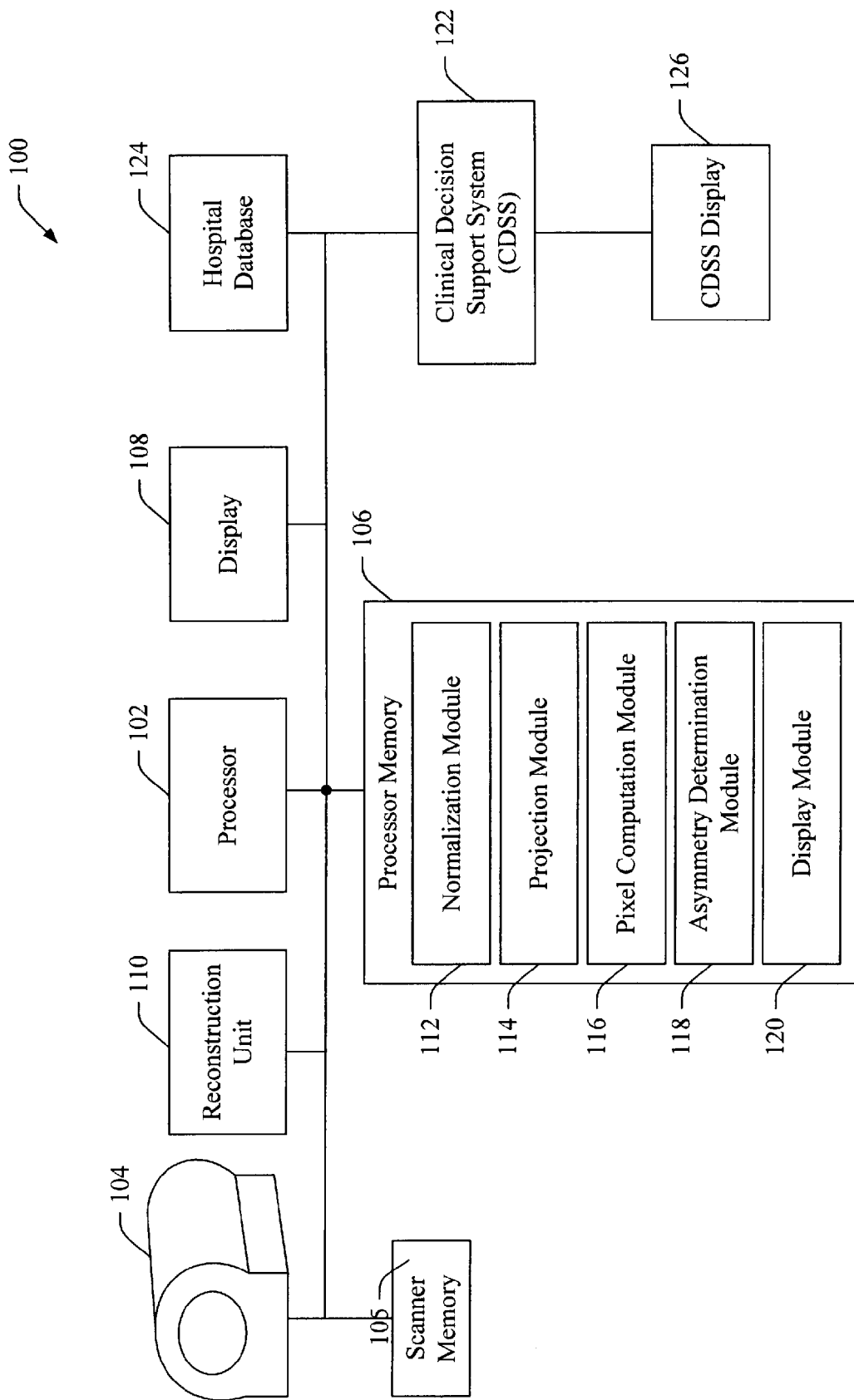


FIG. 1

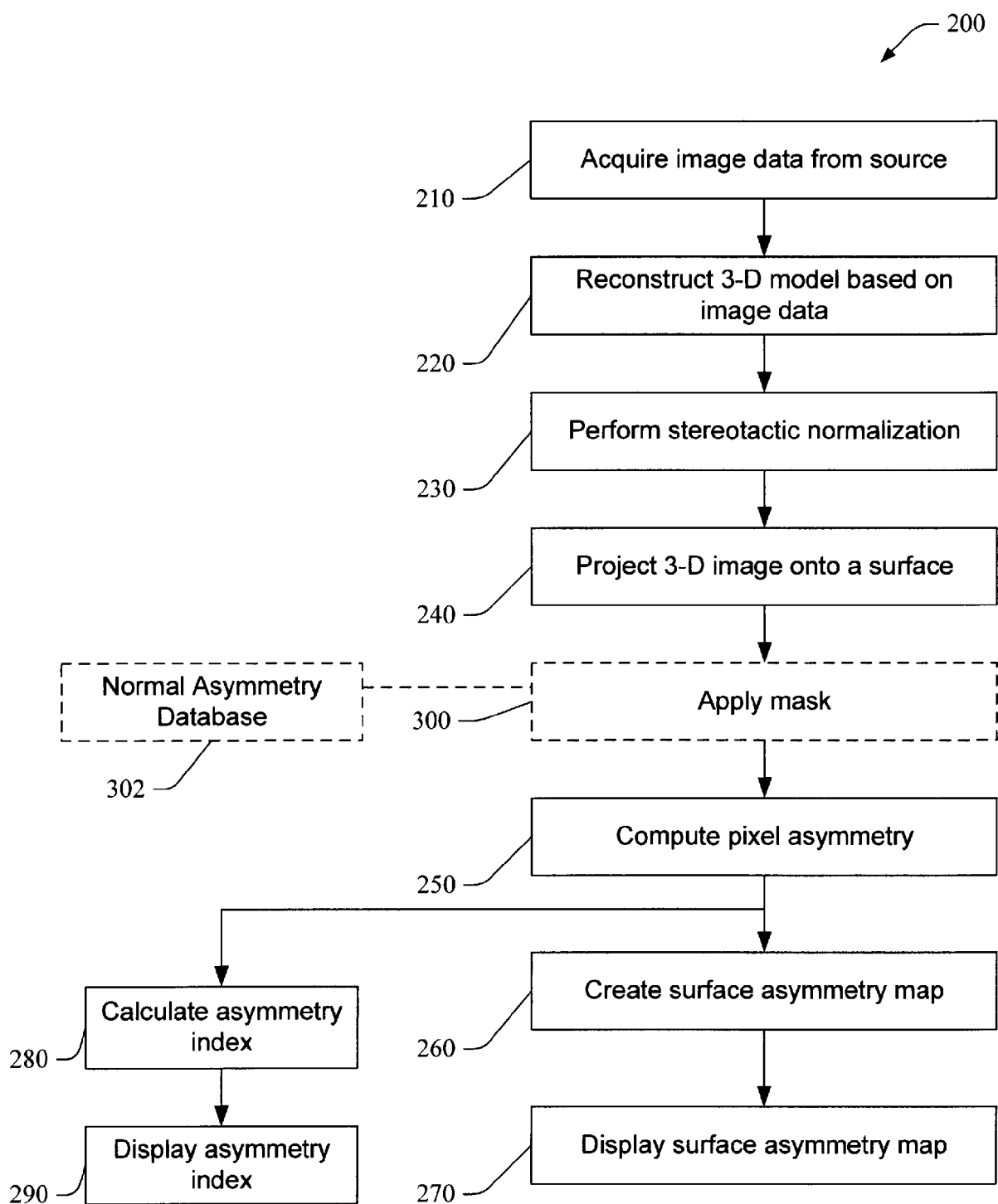


FIG. 2

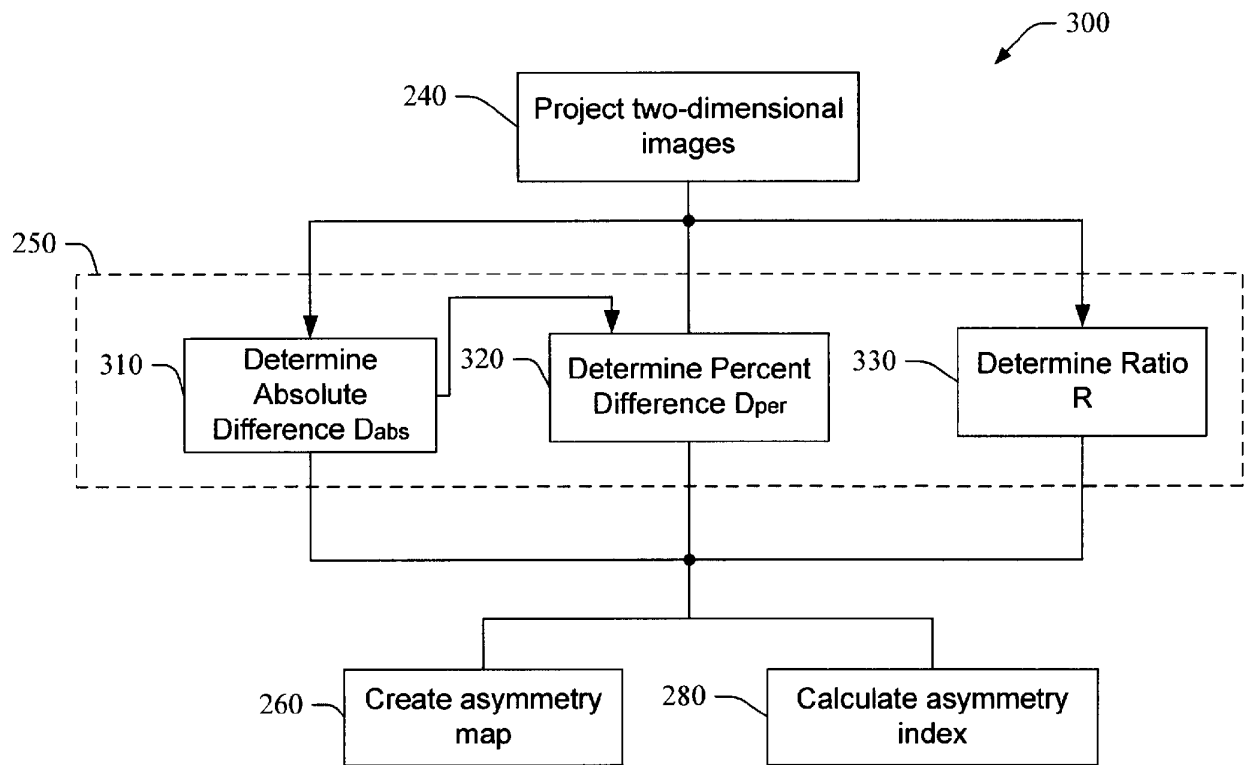


FIG. 3

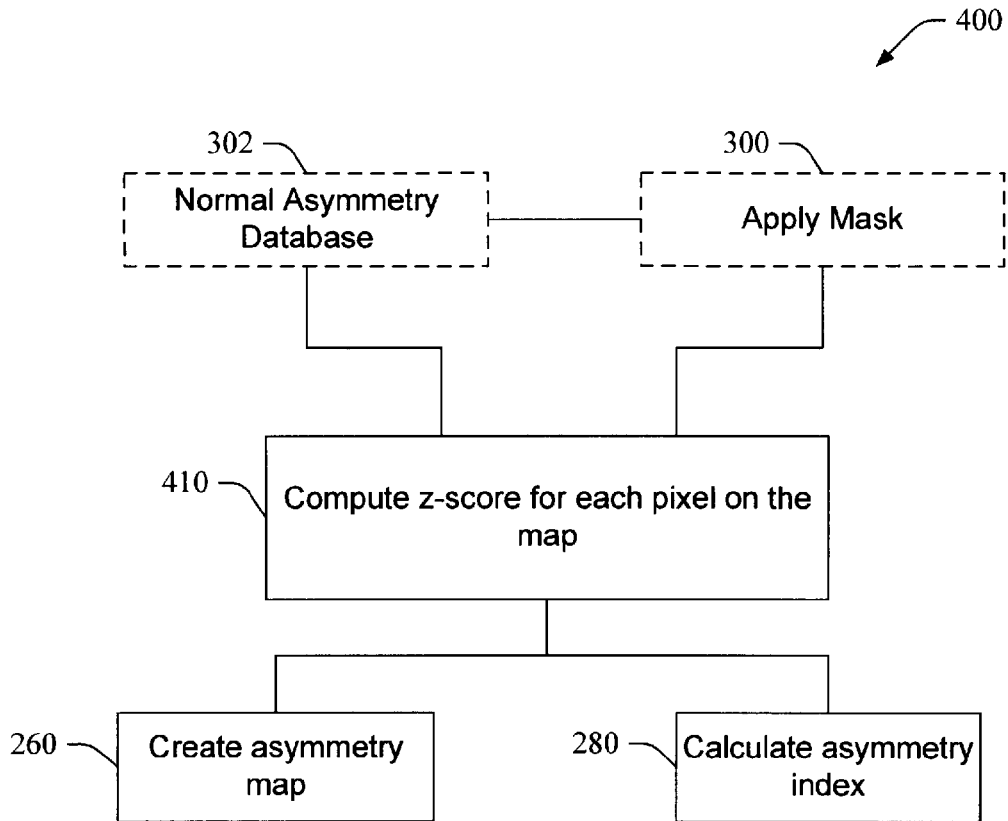


FIG. 4

500

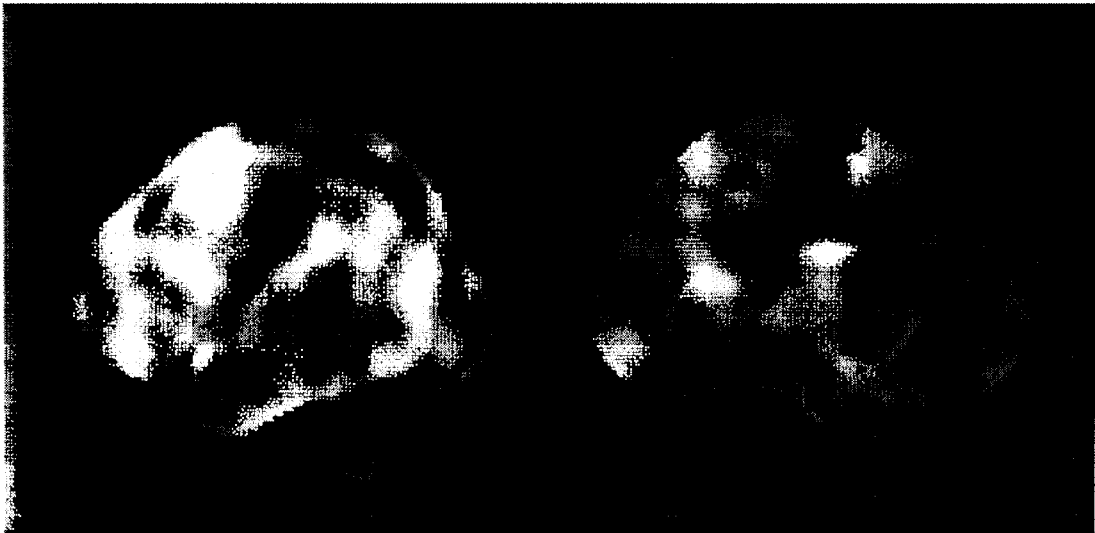


FIG. 5

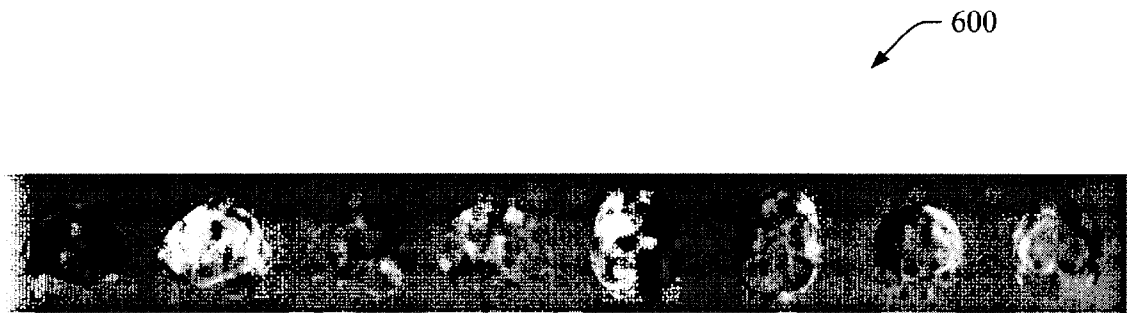


FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **S MINOSHIMA et al.** A diagnostic approach in Alzheimer's disease using three-dimensional stereotactic surface projections of fluorine-18-FDG PET. *Journal of Nuclear Medicine*, vol. 36 (7), 1238-1248 [0007]

专利名称(译)	自动量化不对称		
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摘要(译)

装置检测物体(例如大脑)中的不对称性。该装置包括处理器,该处理器被编程为将物体的三维图像拟合到预选形状,例如标准脑图谱。处理器将对象的三维图像投影到二维表面图像。处理器比较表面图像的左侧和右侧上的相应镜像对称体素对。处理器基于像素对中的偏差生成不对称映射和不对称索引中的至少一个。在比较之前,处理器还可以掩盖表面图像的像素,其在正常脑中是不对称的。

