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[Continued on next page]

(54) Title: ARTICULATED STRUCTURE REGISTRATION IN MAGNETIC RESONANCE IMAGES OF THE BRAIN

(57) Abstract: A registration processor (74) is configured to obtain articulated brain substructures using acquired brain image data and template brain image data. The registration processor (74) annotates the brain image data; registers the brain image data with template image data using global brain registration; and registers at least one brain structure of the brain image data a corresponding brain structure of the template image data using a local brain substructure registration. The registration processor (74) articulates articulated substructures of the registered brain structures to improve registration using articulated substructure registration.

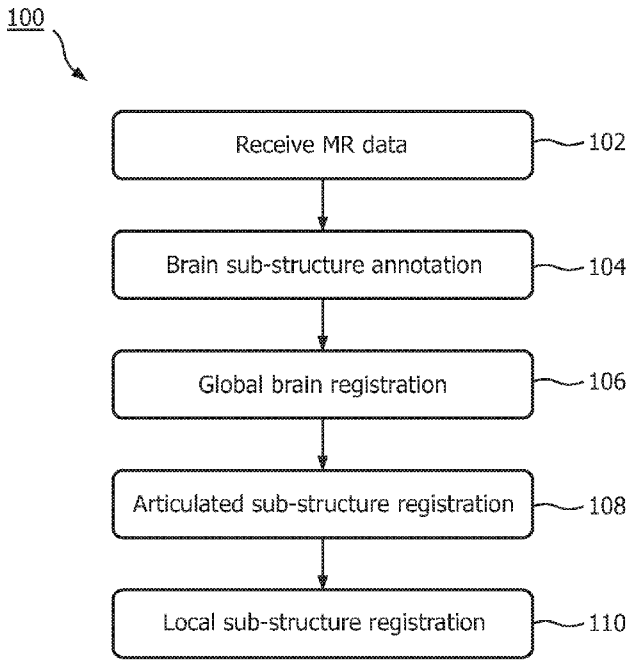


FIG. 2

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ARTICULATED STRUCTURE REGISTRATION IN MAGNETIC RESONANCE IMAGES OF THE BRAIN

Alzheimer's disease and other types of dementia are debilitating conditions affecting millions. Early detection of the onset of such conditions can facilitate early intervention and improve patient health, quality of life, and overall outcome. The conditions have been linked to shrinkage of the hippocampus part of the brain.

The registration of brain magnetic resonance (MR) volumes is a fundamental operation for the processing of brain information. This information is used in the diagnosis of brain tumors, children's brain development, stroke treatments, and neurodegenerative diseases. The registration of one brain – target brain to be processed for diagnosis – to another brain – template or atlas brain that contains known information about its structures –allows clinicians to compare voxel-wise shape and intensity information between the target and template brains. The identification and quantification of shape/intensity differences between the target and template brains allows clinicians to, automatically or semi-automatically, generate features for brain diagnosis.

Current methods for brain registration are divided into: (i) global and (ii) local registration. In the global registration method the whole target brain is registered to the template brain by a combination of translation – of the center of mass – and rotation, such as, by an affine transformation. In the local registration, each voxel in the target brain is transformed to match the shape and intensity characteristics of template brain voxels.

These currently known methods, presented above, propose the registration of 2-D/3-D regions/objects by either global registration, such as, affine registration, or local registration, in computational anatomy, or a combination of both. However, these registration methods do not incorporate object structure information, dealing either with global or local registration.

In accordance with one embodiment, a brain registration system, comprising: a registration processor having a processor configured to: annotate brain image data; register the brain image data with template image data using global brain registration; register at least one brain structure of the brain image data to a corresponding brain structure of the template image data using a local brain sub-structure registration; and articulate articulated sub-structures of the registered brain structures to improve registration using articulated sub-structure registration.

In accordance with one method, a method for brain registration, comprising: annotating brain image data; registering the brain image data with template image data using global brain registration; registering at least one brain structure of the brain image data a corresponding brain structure of the template image data using a local brain sub-structure registration; and articulating articulated sub-structures of the registered brain structures to improve registration using articulated sub-structure registration.

In accordance with another embodiment, a brain registration system, comprising: an annotation module to annotate brain image data; a global registration module to register the brain image data with template image data using global brain registration; a local registration module to register at least one brain structure of the brain image data a corresponding brain structure of the template image data using a local brain sub-structure registration; and an articulation module to articulate articulated sub-structures of the registered brain structures to improve registration using articulated sub-structure registration.

One advantage is increased overlap between a brain MRI and a template brain.

Another advantage is a bridge between global and local brain registration methods.

Still further advantages of the present invention will be appreciated to those of ordinary skill in the art upon reading and understand the following detailed description.

FIGURE 1 depicts an MRI system for articulated structure registration in magnetic resonance images of the brain.

FIGURE 2 depicts a method for articulated structure registration in magnetic resonance images of the brain.

FIGURE 3 depicts an annotated brain sub-structure superimposed on brain tissue.

FIGURE 4 depicts a hippocampus target registered to a template structure.

FIGURE 5 depicts a detailed method for articulated sub-structure registration.

FIGURE 6 depicts a diagram of structure rotation about a joint.

The present application provides a method that works between the global and the local registrations. The present application provides for registration of brain structures which are represented by a set of articulated sub-structures. This takes into account that anatomically and functionally brain structures, such as the hippocampus, thalamus, and the putamen are made of a set of sub-structures. The shape, pose, and intensity of these sub-structures vary from brain to brain and even between different hemispheres of the same brain. Each brain sub-structure is described by a rigid shape and its associated surface intensity values and it is deformed as an articulated object. This articulated deformation describes a set of rotations about the points of contacts that are similar to mechanical hinges. Each sub-structure can also be broken up in smaller sub-parts in order to make the registration as precise as possible.

With reference to FIGURE 1, a magnetic resonance (MR) imaging system **10** utilizes MR to image a region of interest (ROI), i.e. brain, of a patient **12**. The system **10** includes a scanner **14** defining an imaging volume **16** (indicated in phantom) sized to accommodate the ROI. A patient support can be employed to support the patient **12** in the scanner **14** and facilitates positioning the ROI in the imaging volume **16**.

The scanner **14** includes a main magnet **18** that creates a strong, static B_0 magnetic field extending through the imaging volume **16**. The main magnet **18** typically employs superconducting coils to create the static B_0 magnetic field. However, the main magnet **18** can also employ permanent or resistive magnets. Insofar as superconducting coils are employed, the main magnet **18** includes a cooling system, such as a liquid helium cooled cryostat, for the superconducting coils. The strength of the static B_0 magnetic field is commonly one of 0.23 Tesla, 0.5 Tesla, 1.5 Tesla, 3 Tesla, 7 Tesla, and so on in the imaging volume **16**, but other strengths are contemplated.

A gradient controller **20** of the scanner **14** is controlled to superimpose magnetic field gradients, such as x, y and z gradients, on the static B_0 magnetic field in the imaging volume **16** using a plurality of magnetic field gradient coils **22** of the scanner **14**. The magnetic field gradients spatially encode magnetic spins within the imaging volume **16**. Typically, the plurality of magnetic field gradient coils **22** include three separate magnetic field gradient coils spatially encoding in three orthogonal spatial directions.

Further, one or more transmitters **24**, such as a transceiver, are controlled to transmit B_1 resonance excitation and manipulation radiofrequency (RF) pulses into the imaging volume **16** with one or more transmit coil arrays, such as a whole body coil **26**

and/or a surface coil **28**, of the scanner **14**. The B_1 pulses are typically of short duration and, when taken together with the magnetic field gradients, achieve a selected manipulation of magnetic resonance. For example, the B_1 pulses excite the hydrogen dipoles to resonance and the magnetic field gradients encode spatial information in the frequency and phase of the resonance signal. By adjusting the RF frequencies, resonance can be excited in other dipoles, such as phosphorous, which tend to concentrate in known tissues, such as bones.

One or more receivers **30**, such as a transceiver, are controlled to receive spatially encoded magnetic resonance signals from the imaging volume **16** and demodulate the received spatially encoded magnetic resonance signals to MR data sets. The MR data sets include, for example, k-space data trajectories. To receive the spatially encoded magnetic resonance signals, the receivers **30** use one or more receive coil arrays, such as the whole body coil **26** and/or the surface coil **28**, of the scanner **14**. The receivers **30** typically store the MR data sets in a buffer memory.

A backend system **58** of the system **10** images the ROI using the scanner **14**. The backend system **58** is typically remote from the scanner **14** and includes a plurality of modules **60**, discussed hereafter, to perform the imaging of the ROI using the scanner **14**. Advantageously, the backend system can characterize myocardium without the influence of imprecise inversion time selection and provide true quantitative signal quantification on a standardized scale.

A control module **62** of the backend system **58** controls overall operation of the backend system **58**. The control module **62** suitably displays a graphical user interface (GUI) to a user of the backend system **58** using a display device **64** of the backend system **58**. Further, the control module **62** suitably allows the operator to interact with the GUI using a user input device **66** of the backend system **58**. For example, the user can interact with the GUI to instruct the backend system **58** to coordinate the imaging of the ROI.

A data acquisition module **68** of the backend system **58** performs MR scans of the ROI. For each MR scan, the data acquisition module **68** controls the transmitters **24** and/or the gradient controller **20** according to scan parameters, such as number of slices, to implement an imaging sequence within the imaging volume **16**. An imaging sequence defines a sequence of B_1 pulses and/or magnetic field gradients that produce spatially encoded MR signals from the imaging volume **16**. Further, the data acquisition module **68** controls the receivers **30**, and the tune/detune control signal of the driver circuit **36**,

according to scan parameters to acquire spatially encoded MR signals to an MR data set. The MR data set is typically stored in at least one storage memory **70** of the backend system **58**.

In preparing for MR acquisition, the ROI is positioned within the imaging volume **16**. For example, the patient **12** is positioned on the patient support. The surface coil **28**, e.g. a 8 or 32 channel receive head coil, is then positioned on the patient **12** and the patient support moves the ROI into the imaging volume **16**.

A reconstruction module **72** of the backend system **58** reconstructs the MR data sets of the MR diagnostic scans into MR images or maps of the ROI. This includes, for each MR signal captured by the MR data sets, spatially decoding the spatial encoding by the magnetic field gradients to ascertain a property of the MR signal from each spatial region, such as each pixel or voxel. The intensity or magnitude of the MR signal is commonly ascertained, but other properties related to phase, relaxation time, magnetization transfer, and the like can also be ascertained. The acquired MR images or maps can be typically stored in the storage memory **70**. The memory **70** also stores brain templates or atlases which depict normal and/or various disease conditions.

A registration processor **74** of the backend system **58** carries out an enhanced method **100** of articulated structure registration within a target brain, shown in FIGURE 2. The method **100** allows improved registration of segmented structures within the target brain to template brain structures. The method **100** describes the segmentation and registration of with hippocampus sub-structures, but other anatomical structures are also contemplated.

According to the illustrated method **100**, the registration processor **74** receives MR data from the data acquisition module **68**. The MR data includes MR images taken of the target brain or other region of interest. The registration processor **74** then performs brain sub-structure annotation **104**, e.g. segmentation of brain structures of internal and adjacent structures in the imaging region. The segmented structures are identified, e.g. based on location shape, neighboring structures, and the like, and labeled. The brain sub-structure annotation **104** determines an a priori brain sub-structure shape and pose based on expert annotation. With reference to FIGURE 3, expertly annotated hippocampus sub-structures **202** are superimposed on an acquired target brain image.

The registration processor **74** preforms global brain registration **106**. The registration processor **74** first computes the centre of mass (CM) of the acquired target and

reference template MRI brain images based on zero and first order moments. Based on this information the template brain image is translated so that its CM is co-located with the CM of the acquired target brain image. Second, the registration processor **74** computes a three orthogonal axis of orientation for the template and acquired target brain images based on moments, and then rotates the template brain coordinate axes such that it aligns with that of the acquired target brain image's coordinate axes. Third, the registration processor **74** scales the template brain volume of interest along the three coordinate axes so that it maximizes the overlap of the two brain volumes; this is called isotropic moments-based global registration. In one embodiment, scaling is not performed which is called anisotropic moments-based global registration. In one embodiment, global brain registration is performed using registration software such as Elastix.

To find a volume of interest, i.e. the entire hippocampus, the registration processor **74** computes the intersection of boundaries in each orthogonal direction of the template brain. The registration processor **74** uses the template volume of interest to compute the volume of interest of the target brain.

The registration processor **74** performs articulated sub-structure registration **108**. The articulated sub-structure registration uses the existence of articulations inside brain structures to align one articulatable image, e.g. the acquired target brain MRI, to a fixed one, e.g. the template brain image. With reference to FIGURE 4, a registered target hippocampus is overlaid with template brain images, parts of the hippocampus are superimposed and parts are misaligned. Where the hippocampus of the acquired target brain image is registered to the template brain image correctly **302** the image is color coded, e.g. green (diagonal stripe region). Where the hippocampus parts are incorrectly **304** aligned, the target image is color coded, e.g. in red (horizontal striped region), and the misaligned portion of the hippocampus structure **306** in the reference template image is color coded in a third color, e.g. white (white). Articulated sub-structure registration **108** compensates for the incorrect registration **304** by rotating each of the sub-structures, e.g. misaligned hippocampus parts in the acquired target image, such that overlap onto the target and template images **306** increases. The articulated sub-structure registration **108** articulates sub-structures or portions of the hippocampus relative to other portions of the hippocampus to increase the overlap. With reference to FIGURE 5, an articulated hippocampus is shown divided into sub-structures according to parts of the hippocampus.

The sub-structures include the subiculum **SUB**, dentate gyrus **DG**, enthorinal cortex **EC**, or cornu ammonis **CA1**, **CA2**, **CA3**.

To find a volume of interest of each sub-structure, the registration processor **74** computes the intersection of boundaries in each orthogonal direction of the template brain. The registration processor **74** uses the template sub-structure volumes of interest to compute the sub-structure volumes of interest of the target brain.

The registration processor **74** performs a local brain registration **110** to register target brain structures to template brain structures. The local registration transforms each voxel in a target brain image to match the shape and intensity characteristics of corresponding template brain image voxels. The local brain registration includes, for example, applying BSplines for local pixel (voxel) intensity interpolation. In one embodiment, local brain registration is performed using registration software such as Elastix or FSL FLIRT.

With reference to FIGURE 6, the registration processor **74** performs articulated sub-structure registration **108** by first computing brain sub-structure linking joints **502**. Linking joints are linking points by which two sub-structures, e.g. misaligned and aligned hippocampus portions are connected. MR image pixels/voxels are mapped to a physical point in the space such that every pixel contains the intensity value of the image and the physical position of that value. The registration processor **74** represents the joint between two sub-structures as a physical point in the space. With reference to FIGURE 7, two objects **602**/**604** in an image represent two sub-structures, such as hippocampus portions **302** and **304** in Fig. 4. The registration processor **74** finds the joint **606** as the brain sub-structure linking joint. The registration processor **74** calculates the joint **606** by calculating a pair of pixels/voxels (one pixel/voxel from structure **602** and one pixel from structure **604**) with minimum Euclidean distance between them. In one embodiment, a set of pairs of pixels is calculated because there might be more than one pair with the same minimum distance. The registration processor **74** calculates the pairs with minimum Euclidian distance by obtaining all combinations of pairs of pixels/voxels and comparing the distance between each pair. The registration processor **74** calculates the average location of each of the pixels/voxels from each structure **602**,**604** from the calculated set of pairs to find an extreme point of each structure. The registration processor **74** computes the middle point between the extreme points as the joint **606**.

The registration processor **74** applies a rotation **504** about the calculated joint **606** to maximize alignment. In the hippocampus example, the registration processor **74** rotates the misaligned portion of the hippocampus in the acquired target brain image about the joint **606** to optimize the alignment with the corresponding hippocampus portion in the template brain image. The registration processor **74** first calculates a similarity metric **506** between the acquired image and the template image to maximize the similarity between the images according to the similarity metric. The similarity metric can be one of sum of square differences, normalized correlation coefficient, or mutual information metrics and the like. Using the similarity metric, the registration processor **74** calculates an optimal transformation e.g. articulating movement. In one embodiment, the registration processor **74** uses an iterative process to calculate the optimal transform in which the registration processor **74** applies a rotation of a preselected amount and computes the similarity metric, then increases the rotation about the joint **606** and re-computes the similarity metric. The registration processor **74** iteratively applies the transform to the MRI binary image which maximizes overlap between the target structure and the MRI image.

Each of the plurality of modules **60, 100, 110** can be embodied by processor executable instructions, circuitry (i.e., processor independent), or a combination of the two. The processor executable instructions are stored on at least one program memory **76** of the backend system **58** and executed by one or more processors **78** of the backend system **58**. As illustrated, the plurality of modules **60** is embodied by processor executable instructions. However, as is to be appreciated, variations are contemplated. For example, the data acquisition module **68** can be circuitry.

As used herein, a memory includes one or more of: a non-transient computer readable medium; a magnetic disk or other magnetic storage medium; an optical disk or other optical storage medium; a random access memory (RAM), read-only memory (ROM), or other electronic memory device or chip or set of operatively interconnected chips; an Internet/Intranet server from which the stored instructions may be retrieved via the Internet/Intranet or a local area network; and the like. Further, as used herein, a processor includes one or more of a microprocessor, a microcontroller, a graphic processing unit (GPU), an application-specific integrated circuit (ASIC), an FPGA, and the like; a controller includes: (1) a processor and a memory, the processor executing computer executable instructions on the memory embodying the functionality of the

controller; or (2) analog and/or digital hardware carrying out the functionality of the controller; a user input device includes one or more of a mouse, a keyboard, a touch screen display, a button, a switch, a voice recognition engine, and the like; a database includes one or more memories; a user output device includes a display device, a auditory device, and the like; and a display device includes one or more of a liquid crystal display (LCD) display, a light emitting diode (LED) display, a plasma display, a projection display, a touch screen display, and the like.

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

CLAIMS:

1. A brain registration system, comprising:

a registration processor (74) having a processor configured to:

annotate brain image data;

register the brain image data with template image data using global brain registration;

articulate articulated sub-structures of the registered brain structures to improve registration using articulated sub-structure registration; and

register at least one brain structure of the brain image data to a corresponding brain structure of the template image data using a local brain sub-structure registration .

2. The system according to claim 1, wherein the registration processor (74) is further configured to:

identify a linking joint between the articulated sub-structures.

3. The system according to claim 2, wherein the registration processor (74) is further configured to:

rotate the at least one brain sub-structure about the linking joint to maximize overlap.

4. The system according to any one of claims 1-3, wherein the registration processor (74) is further configured to:

compute a similarity metric between the at least one brain structure and the corresponding template structure.

5. The system according to any one of claims 2-4, wherein the registration processor (74) is further configured to:

iteratively rotate the sub-structure in one of the brain image data and the template image data about the linking joint and computing a similarity metric between the brain image sub-structure and the template image sub-structure for each iteration; and

select the iteration that maximizes the similarity metric.

6. The system according to any one of claims 1-5, wherein the registration processor is (74) further configured to:

apply a transform to the brain image data to maximize overlap between the at least one brain structure and the corresponding template structure.

7. The system according to any one of claims 2-6, wherein the registration processor (74) is further configured to:

calculate a Euclidian distance for all pairs of pixels/voxels between the articulated sub-structures;

select a pair of pixels/voxels having a minimum Euclidian distance; and

compute a middle point between the selected pair of pixels/voxels as the linking joint between the sub-structures.

8. The system according to any one of claims 1-7, wherein the global brain registration includes an isotropic moments-based global registration.

9. A method for brain registration, comprising:

annotating brain image data;

registering the brain image data with template image data using global brain registration;

articulating articulated sub-structures of the registered brain structures to improve registration using articulated sub-structure registration; and

registering at least one brain structure of the brain image data to a corresponding brain structure of the template image data using a local brain sub-structure registration.

10. The method according to claim 9, the articulated sub-structure registration including:

identifying a linking joint between the articulated sub-structures.

11. The method according to claim 10, the articulated sub-structure registration including:

rotating the at least one brain sub-structure about the linking joint to maximize overlap.

12. The method according to claim 11, the articulated sub-structure registration including:

computing a similarity metric between the at least one brain structure and the corresponding template structure.

13. The method according to claim 10, the articulated sub-structure registration including:

iteratively rotating the sub-structure in one of the brain image data and the template image data about the linking joint and computing a similarity metric between the brain image sub-structure and the template image sub-structure for each iteration; and

selecting the iteration that maximizes the similarity metric.

14. The method according to any one of claims 9-13, including:

applying a transform to the brain image data to maximize overlap between the at least one brain structure and the corresponding template structure.

15. The method according to claim 10, wherein computing the linking joint includes:

calculating a Euclidian distance for all pairs of pixels/voxels between the articulated sub-structures;

selecting a pair of pixels/voxels having a minimum Euclidian distance; and

computing a middle point between the selected pair of pixels/voxels as the linking joint between the sub-structures.

16. The method according to any one of claims 9-16, wherein the global brain registration includes an isotropic moments-based global registration.

17. A non-transitory computer readable medium having instructions to perform the method of any one of claims 9-16.

18. A brain registration system, comprising:

an annotation module to annotate brain image data;

a global registration module to register the brain image data with template image data using global brain registration;

an articulation module to articulate articulated sub-structures of the registered brain structures to improve registration using articulated sub-structure registration; and

a local registration module to register at least one brain structure of the brain image data a corresponding brain structure of the template image data using a local brain sub-structure registration.

19. The system according to claim 18, including:

an identification module to identify a linking joint between the articulated sub-structures;

a rotation module to rotate the at least one brain sub-structure about the linking joint to maximize overlap;

a metric module to compute a similarity metric between the at least one brain structure and the corresponding template structure; and

a transform module to apply a transform to the brain image data to maximize overlap between the at least one brain structure and the corresponding template structure.

20. The system according to any one of claims 18-19, including:

a iteration module to iteratively rotate the sub-structure in one of the brain image data and the template image data about the linking joint and computing a similarity metric between the brain image sub-structure and the template image sub-structure for each iteration; and

a selection module to select the iteration that maximizes the similarity metric.

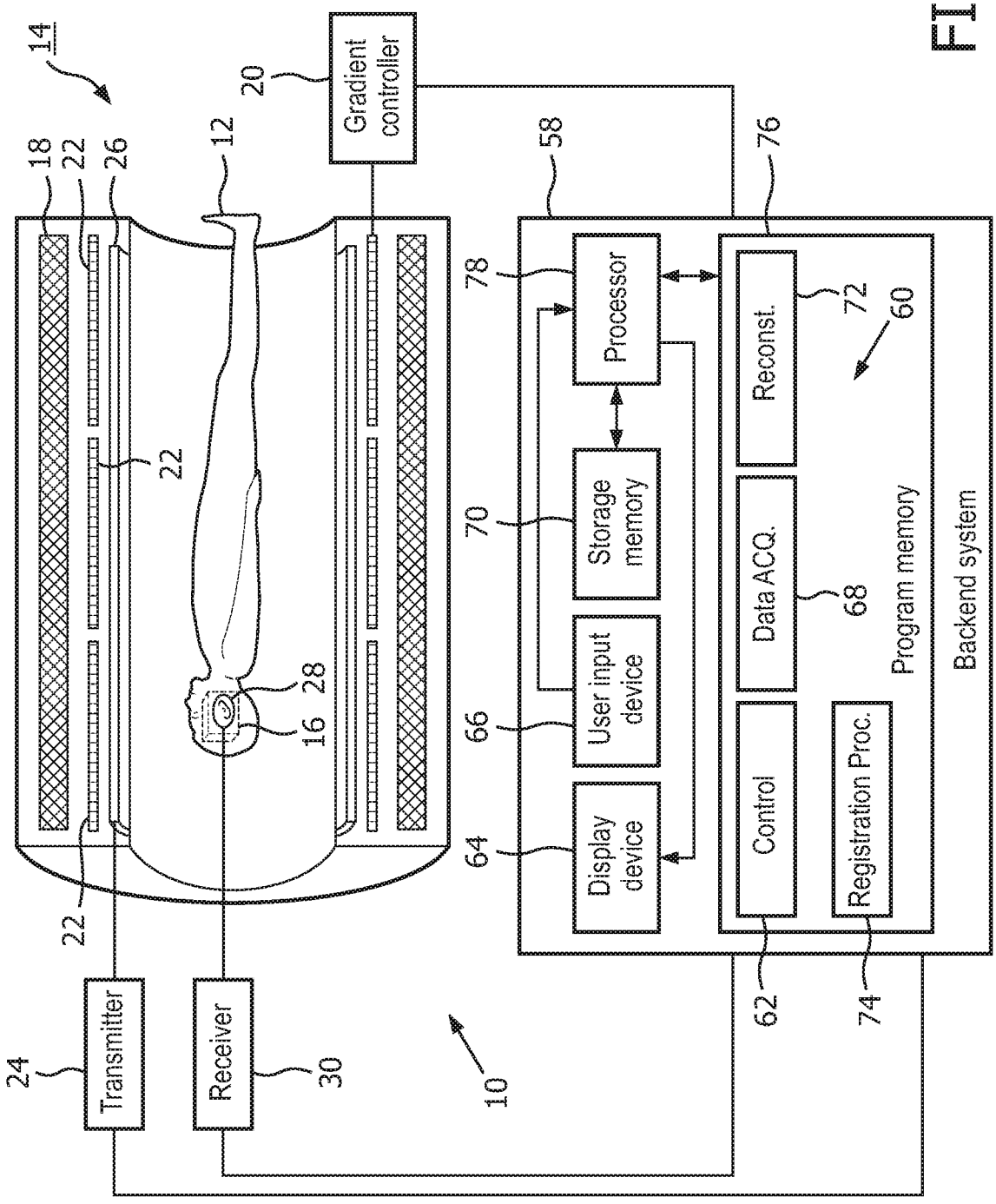

14
18
22
26
12
20
Gradient controller
58
76
78
Processor
72
Reconst.
60
22
70
Storage memory
Data ACQ.
68
Program memory
Backend system
28
16
66
User input device
64
Display device
Control
Registration Proc.
22
24
Transmitter
Receiver
30
10
62
74

FIG. 1

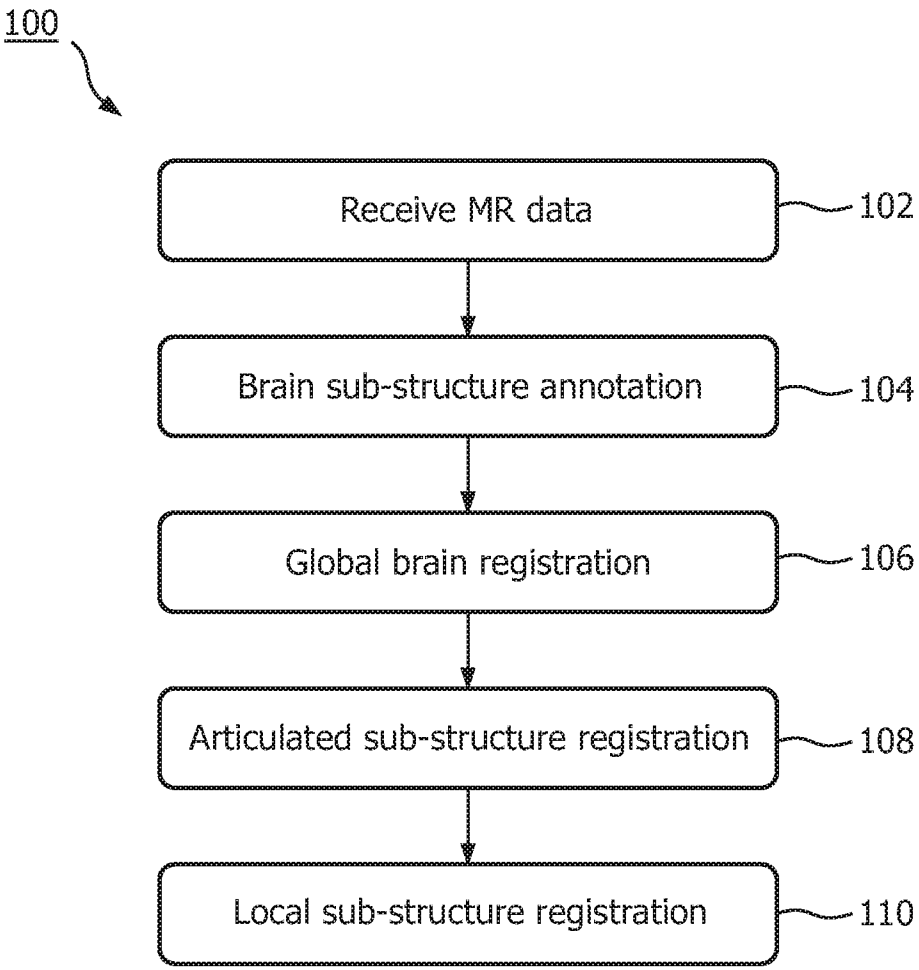
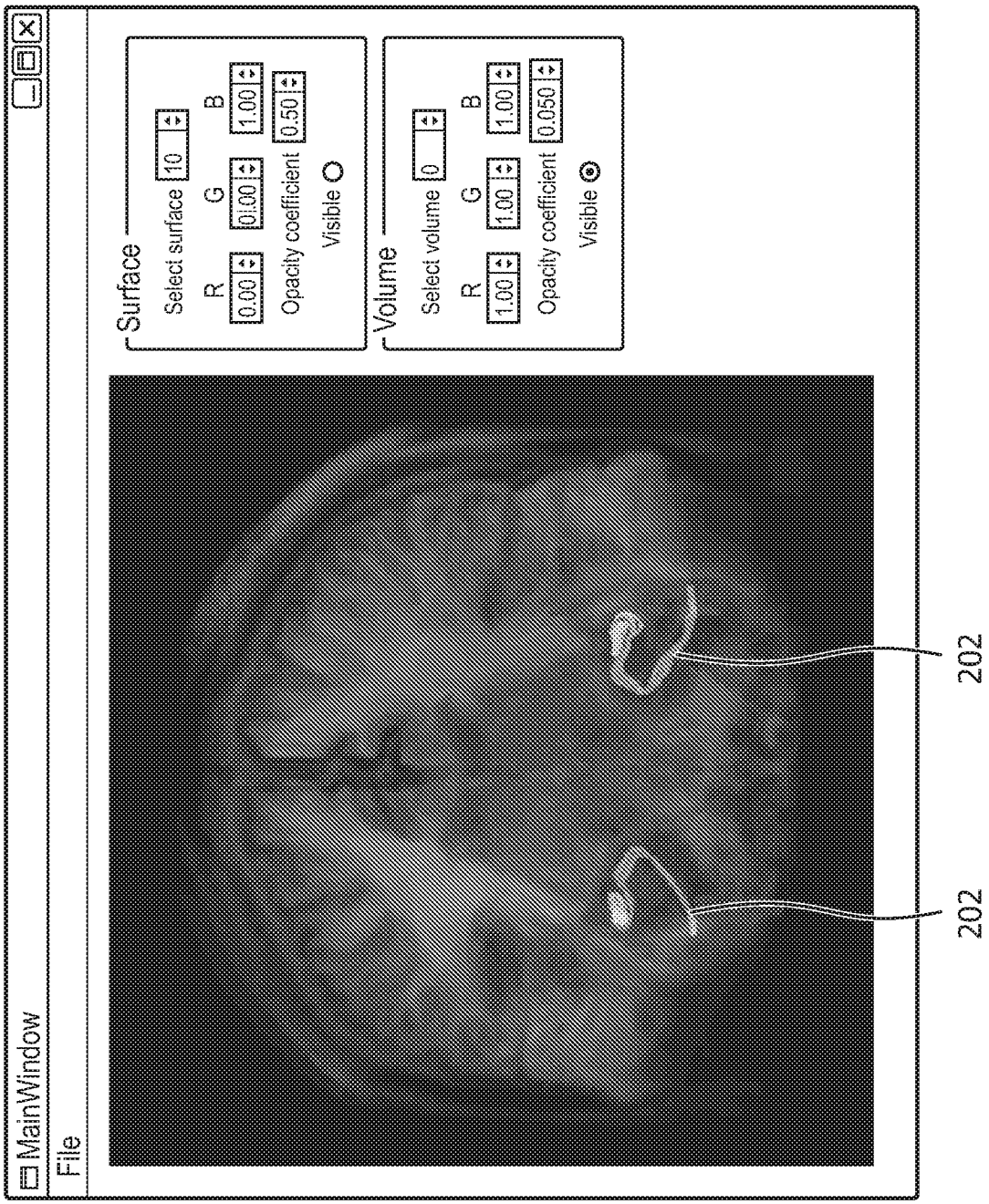

100
Receive MR data
102
Brain sub-structure annotation
104
Global brain registration
106
Articulated sub-structure registration
108
Local sub-structure registration
110

FIG. 2

FIG. 3


MainWindow
File
Surface
Select surface 10
R G B
0.00 0.00 1.00
Opacity coefficient 0.50
Visible
Volume
Select volume 0
R G B
1.00 1.00 1.00
Opacity coefficient 0.050
Visible
202
202

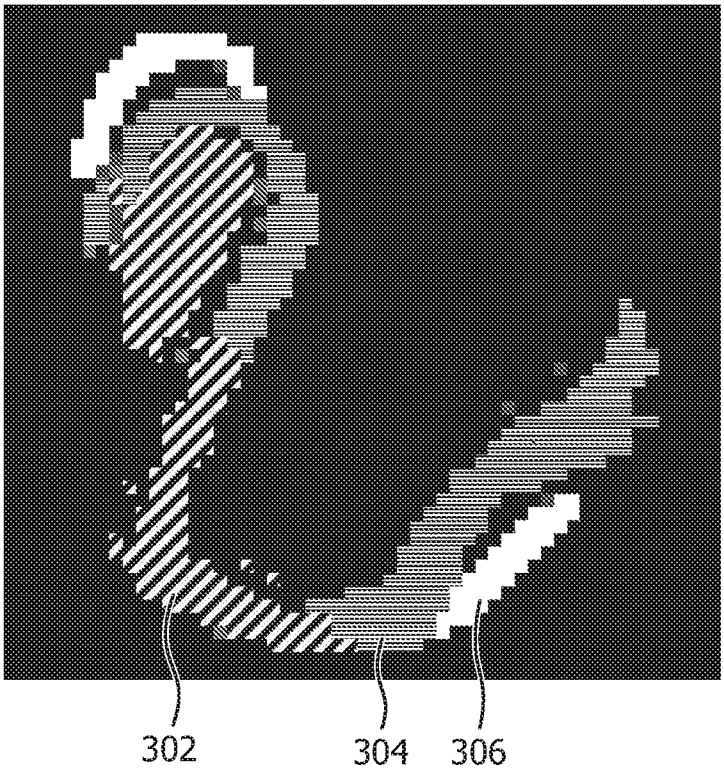


FIG. 4

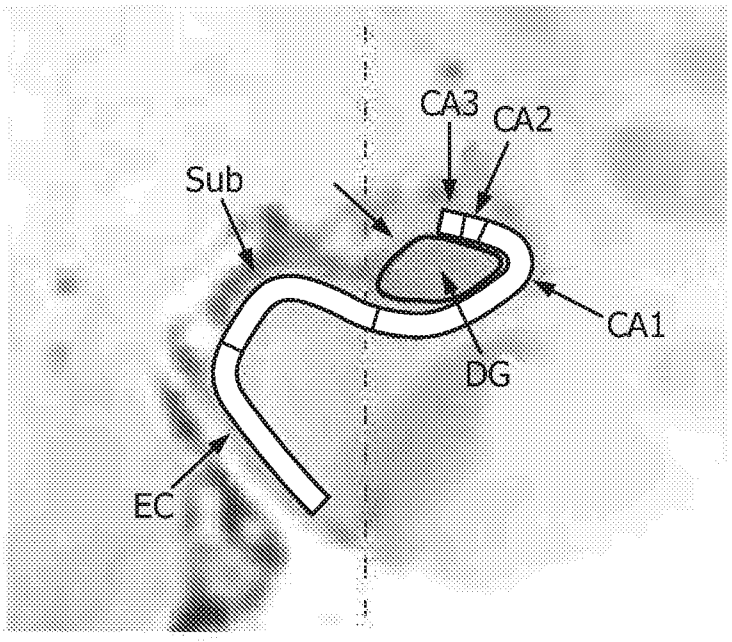


FIG. 5

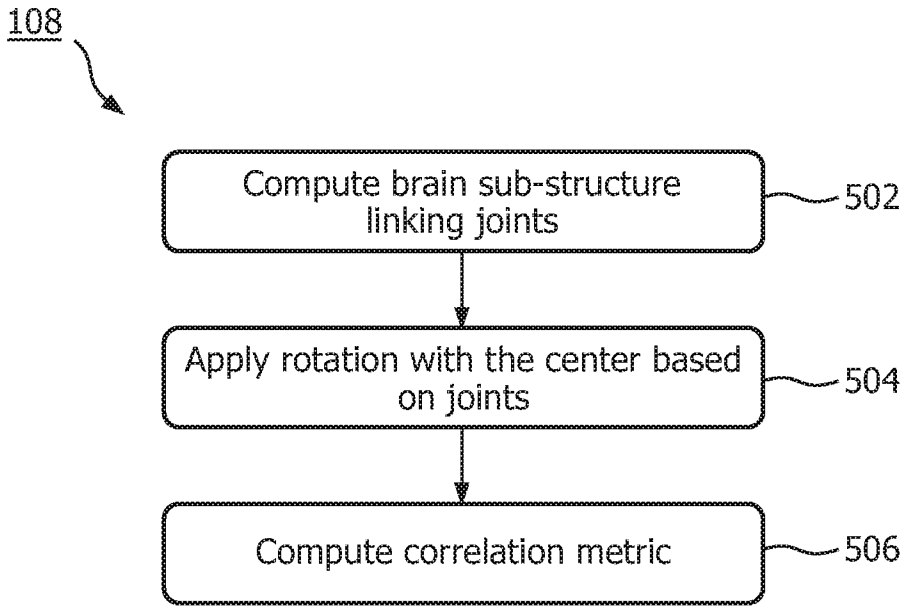

108
Compute brain sub-structure linking joints
502
Apply rotation with the center based on joints
504
Compute correlation metric
506

FIG. 6

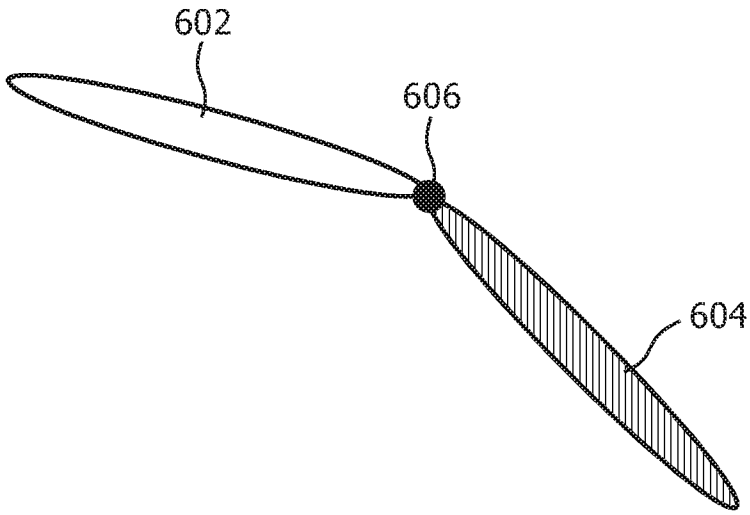

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FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/050083

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06T7/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06T

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

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

EPO-Internal, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CHUI H ET AL: "REGISTRATION OF CORTICAL ANATOMICAL STRUCTURES VIA ROBUST 3D POINT MATCHING", INFORMATION PROCESSING IN MEDICAL IMAGING. INTERNATIONALCONFERENCE. PROCEEDINGS, XX, XX, 28 June 1999 (1999-06-28), pages 168-181, XP000974871,	1-6, 9-14, 17-20
Y	abstract	8,16
A	sections 1, 3, 4.3 figure 1	7,15
	----- -/--	

[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 application or patent but published on or after the international filing date

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"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
24 April 2015	06/05/2015

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, Fax: (+31-70) 340-3016	Eveno, Nicolas

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

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/050083

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PITIOT A ET AL: "Piecewise affine registration of biological images for volume reconstruction", MEDICAL IMAGE ANALYSIS, OXFORD UNIVERSITY PRESS, OXOFRD, GB, vol. 10, no. 3, 1 June 2006 (2006-06-01), pages 465-483, XP028013470, ISSN: 1361-8415, DOI: 10.1016/J.MEDIA.2005.03.008 [retrieved on 2006-06-01]	1-3,6, 9-11,14, 17,18
Y	abstract sections 1.3.4, 2 figures 3,8,11	8,16

X	COMMOWICK O ET AL: "An efficient locally affine framework for the smooth registration of anatomical structures", MEDICAL IMAGE ANALYSIS, OXFORD UNIVERSITY PRESS, OXOFRD, GB, vol. 12, no. 4, 1 August 2008 (2008-08-01) , pages 427-441, XP022834269, ISSN: 1361-8415, DOI: 10.1016/J.MEDIA.2008.01.002 [retrieved on 2008-01-31]	1-6, 9-14, 17-20
Y	abstract	8,16
A	sections 2.1, 2.2.1, 2.3, 2.3.2, 2.5, 3.1.1 figures 1,4-6	7,15

Y	Gerardo Santiago Flores ET AL: "Automatic Segmentation of Hippocampal Substructures", , 2 July 2012 (2012-07-02), XP055185638, Retrieved from the Internet: URL:http://alexandria.tue.nl/extra1/afstverslag/wsk-i/flores2012.pdf [retrieved on 2015-04-24] section 3.3	8,16

A	WO 2013/023073 A1 (BOSTON SCIENT NEUROMODULATION [US]; BLUM DAVID ARTHUR [US]; KOKONES SC) 14 February 2013 (2013-02-14) paragraphs [0169], [0170], [0188], [0190]	1-20

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2015/050083

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013023073 A1	14-02-2013	AU 2012294356 A1	20-03-2014
		CA 2844072 A1	14-02-2013
		EP 2742482 A1	18-06-2014
		US 2013039550 A1	14-02-2013
		WO 2013023073 A1	14-02-2013