EUROPEAN PATENT SPECIFICATION

SYSTEM FOR SHAPE SENSING ASSISTED MEDICAL PROCEDURE

SYSTEM FÜR FORMMESSUNGSUNTERSTÜTZTES MEDIZINISCHES VERFAHREN

SYSTEME POUR UNE PROCÉDURE MÉDICALE ASSISTÉE PAR DÉTECTION DE FORME

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This disclosure relates to shape sensing assisted procedures and more particularly to a system for utilizing shape sensing data to navigate a complex biological or mechanical system.

Taking tissue samples during bronchoscopy is a difficult task and has a low rate of success. During an intervention, a bronchoscope is inserted in the airways so that a physician can navigate to a target. However, the topology of the airways is very complex and the physician can easily get lost while going further down the bronchial tree.

One bronchoscope issue is that the bronchoscope provides only local information. In current clinical practice, a computed tomography (CT) image is typically acquired prior to the intervention for diagnosis and target definition. On the basis of the CT, computer tools assist the workflow, e.g., segmentation of desired structures, optimal path calculation to the target, etc. Furthermore, the CT provides more global information of the patient’s anatomy that can be used during the intervention. To track the path and register the bronchoscopic image with its position, electromagnetic (EM) tracking is usually employed. However, as the patient breathes during the intervention, a misalignment between CT and a bronchoscopic image limits the use of the image rendering. Real time X-ray imaging may also be employed to follow the device.

International Patent Application WO2010111090A1 describes providing guidance to an operator of an endoscopic device by displaying graphical representations of vectors adjacent a current image captured by an image capturing device disposed at a tip of the endoscopic device and being displayed on a display screen. The graphical representations of the vectors point in directions that the endoscope tip is to be steered in order to move towards associated landmarks such as anatomic structures. Navigation guidance is provided to the operator by determining a current position and shape of the endoscope, generating an endoscope computer model according to the determined position and shape, and displaying the endoscope computer model along with a patient computer model.

European Patent Application EP1504713A1 describes an image guided navigation system for navigating a region of a patient that includes an imaging device, a tracking device, a controller, and a display. The imaging device generates images of the region of a patient. The tracking device tracks the location of the instrument in a region of the patient. The controller superimposes an icon representative of the instrument onto the images generated from the imaging device based upon the location of the instrument. The display displays the image with the superimposed instrument.

In accordance with the present principles, a system for shape sensing assistance in a medical procedure is provided. One aim is to provide the physician with some information and feedback if a desired path was chosen.

A system according to the invention comprises: a memory configured to store a three-dimensional image of a distributed pathway system; a shape sensing enabled elongated device configured for insertion into the pathway system and configured to measure a shape of the elongated device in the pathway system; and a pathway determination module configured to compute paths in the three-dimensional image. The system is characterized in that the pathway determination module is further configured to repeatedly compare the measured shape with the paths in the three-dimensional image to determine whether a given path has been selected relative to a target.

These and other objects, features and advantages of the present disclosure will become apparent from the following detailed description of illustrative embodiments thereof, which is to be read in connection with the accompanying drawings.

The invention is defined in the appended independent claim. Embodiments of the invention are defined in the dependent claims. The use of the word "embodiment" below in this description merely implies the illustration of examples or exemplary embodiments, if not otherwise defined by the appended claims. The scope of the invention is thus defined by the appended claims.

This disclosure will present in detail the following description of preferred embodiments with reference to the following figures wherein:

FIG. 1 is a block/flow diagram showing a system/method for shape sensing assistance in a medical procedure in accordance with the present principles;

FIG. 2 is a diagram showing a centerline generated in a bifurcated image and for a shape sensed device for comparison in determining if a correct path has been taken in accordance with one embodiment;

FIG. 3 is a diagram showing centerlines generated in bifurcated images and shape sensed measurement for a deforming organ for comparison in determining if a correct path has been taken in accordance with another embodiment; and

FIG. 4 is a block/flow diagram showing a method for shape sensing assistance in a medical procedure in accordance with the present principles.

In accordance with the present principles, device navigation is improved during a procedure by extracting shape-sensing data of a device. Tracking technology permits reconstruction of device shapes along a length of the device. The shape-sensed data and tracked position are then correlated with previously collected images. With shape sensing, three-dimensional (3D) information of the shape of the device (thus 3D information, e.g., compared to 2D information provided by X-ray or sparse 3D point information from electromagnetic tracking) is available. This shape information is of particular
interest in complex systems, such as the airways in lungs, where the shape information can be employed to assist a physician to validate whether a correct path has been selected. Furthermore, sensors are attached to the device and can account for deformations caused by breathing or heart beat so that this motion can be compensated.  

In one illustrative example, during a bronchoscopic procedure, a physician may attempt to reach a target with a bronchoscope that is inserted through the airways of the embryos with reference to the following figures wherein:

FIG. 1 is a block/flow diagram showing a system/method for shape sensing assistance in a medical procedure in accordance with the present principles;

FIG. 2 is a diagram showing a centerline generated in a bifurcated image and for a shape sensed device for comparison in determining if a correct path has been taken in accordance with one embodiment;

FIG. 3 is a diagram showing centerlines generated in bifurcated images and shape sensed measurement for a deforming organ for comparison in determining if a correct path has been taken in accordance with another embodiment; and

FIG. 4 is a block/flow diagram showing a method for shape sensing assistance in a medical procedure in accordance with the present principles.

In accordance with the present principles, device navigation is improved during a procedure by extracting shape-sensing data of a device. Tracking technology permits reconstruction of device shapes along a length of the device. The shape-sensed data and tracked position are then correlated with previously collected images. With shape sensing, three-dimensional (3D) information of the shape of the device (thus 3D information, e.g., compared to 2D information provided by X-ray or sparse 3D point information from electromagnetic tracking) is available. This shape information is of particular interest in complex systems, such as the airways in lungs, where the shape information can be employed to assist a physician to validate whether a correct path has been selected. Furthermore, sensors are attached to the device and can account for deformations caused by breathing or heart beat so that this motion can be compensated.

In one illustrative example, during a bronchoscopic procedure, a physician may attempt to reach a target with a bronchoscope that is inserted through the airways of the lungs. The topology of the airways is very complex which often causes physicians to navigate wrong paths. Even if pre-operative imaging data is available for guidance, deformations due to breathing or patient repositioning compromise successful targeting. The present principles employ shape sensing information obtained from the bronchoscope to reconstruct bronchoscope shapes along whole instrument lengths. This information can be used to overcome current limitations in bronchoscopic interventions by permitting a check between correct and incorrect device shapes which indicate correct or incorrect pathways to a target.

It should be understood that the present invention will be described in terms of medical instruments; however, the teachings of the present invention are much broader and are applicable to any instruments employed in tracking or analyzing complex biological or mechanical systems. In particular, the present principles are applicable to internal tracking procedures of biological systems, procedures in all areas of the body such as the lungs, gastrointestinal tract, excretory organs, blood vessels, etc. The elements depicted in the FIGS. may be implemented in various combinations of hardware and software and provide functions which may be combined in a single element or multiple elements.

The functions of the various elements shown in the FIGS. can be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions can be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which can be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and can implicitly include, without limitation, digital signal processor ("DSP") hardware, read-only memory ("ROM") for storing software, random access memory ("RAM"), non-volatile storage, etc.

Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific elements thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future (i.e., any elements developed that perform the same function, regardless of structure).

Thus, for example, it will be appreciated by those skilled in the art that the block diagrams presented herein represent conceptual views of illustrative system components and/or circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams and the like represent various processes which may be substantially represented in computer readable storage media and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

Furthermore, embodiments of the present invention can take the form of a computer program product accessible from a computer-readable or computer-readable storage medium providing program code for use by or in connection with a computer or any instruction execution system. For the purposes of this description, a computer-readable or computer-readable storage medium
can be any apparatus that may include, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The medium can be an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system (or apparatus or device) or a propagation medium. Examples of a computer-readable medium include a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk. Current examples of optical disks include compact disk - read only memory (CD-ROM), compact disk - read/write (CD-R/W) and DVD.

[0019] Referring now to the drawings in which like numerals represent the same or similar elements and initially to FIG. 1, a system 100 for performing a medical procedure is illustratively depicted. System 100 may include a workstation or console 112 from which a procedure is supervised and managed. Workstation 112 preferably includes one or more processors 114 and memory 116 for storing programs and applications. Memory 116 may store an optical sensing module 115 configured to interpret optical feedback signals from a shape sensing device 104. Optical sensing module 115 is configured to use the optical signal feedback (and any other feedback, e.g., electromagnetic (EM)) to reconstruct deformations, deflections and other changes associated with a medical device 102 and/or its surrounding region. The medical device 102 may include, e.g., a catheter, a guide wire, an endoscope, a probe, a robot, an electrode, a filter device, a balloon device, or other medical component, etc. Workstation 112 may include a display 118 for viewing internal images of a subject if an imaging system 110 is employed. The imaging system 110 may include, e.g., a magnetic resonance imaging (MRI) system, a fluoroscopy system, a computed tomography (CT) system, etc. Display 118 may also permit a user to interact with the workstation 112 and its components and functions. This is further facilitated by an interface 120 which may include a keyboard, mouse, a joystick or any other peripheral or control to permit user interaction with the workstation 112.

[0020] Workstation 112 includes an optical source 106 to provide optical fibers with light. An optical interrogation unit 108 is employed to detect light returning from all fibers. This permits the determination of strains or other parameters, which will be used to interpret the shape, orientation, etc. of the interventional device 102. The light signals will be employed as feedback to make adjustments to access errors and to calibrate the device 102 or system 100.

[0021] Shape sensing device 104 includes one or more fibers which are configured to exploit their geometry for detection and correction/calibration of a shape of the device 102. Optical interrogation unit/module 108 works with optical sensing module 115 (e.g., shape determination program) to permit tracking of instrument or device 102.

[0022] Imaging system 110 may be provided for collecting pre-operative imaging data or real-time intra-operative imaging data. The pre-operative imaging may be performed at another facility, location, etc. in advance of any procedure. These 3D images 111 may be stored in memory 116.

[0023] In a particularly useful embodiment, device 102 is employed to discover or observe a target. The target may include a lesion, injury site, object or other target. During the procedure, shape sensing data from shape sensing device 104 is collected and registered with the pre-operative imaging data. A registration module 140 determines registration positions and registers the shape sensing data with the pre-operative images 111, which are preferably 3D images. The shape sensing data may include motion data from a heartbeat and/or breathing and motion compensation may be performed to account for the same in the images (e.g., deformations due to breathing can be measured using shape sensing). The 3D images 111 may include these motion compensated images.

[0024] A pathway determination module 144 computes paths and compares rich point data from shape sensing data registered with the motion compensated images to determine whether a correct path was followed. The position and the shape of the device 102 is compared with the motion compensated images by matched pathways, e.g., in the lungs, with the shape of the device 102. If lumen walls appearing in the compensated image overlap the shape sensing data positions then a wrong pathway has been taken.

[0025] When a wrong path has been taken, the system 100 provides feedback to the clinician or physician. The feedback may take a plurality of different forms. For example, a visualization may be provided on display 118 which provides feedback to the physician that a wrong path was traveled and where the mistake most probably occurred to take corrective measures. Another embodiment provides an audible alarm when an incorrect path has been taken.

[0026] System 100 may include a warning mechanism 146 configured to indicate that an incorrect path has been selected. The warning mechanism 146 may take many forms and may be included in components that are already a part of the system 100. The warning mechanism 148 may include one or more of the following features. The display 118 may be employed to display a location the incorrect path was selected so that a physician can go back and make corrections. In addition or alternatively, a visual (display 118) or audible (e.g., a speaker at interface 120) indicator may be generated when an incorrect path is selected. The warning mechanism 146 may be employed to warn of an imminent incorrect selection to effectively guide the physician during a procedure.

[0027] In one useful embodiment, the device 102 includes a bronchoscope, a pathway system 148 being analyzed includes a lung and the shape sensing includes a bronchoscope, a pathway system 148 being analyzed includes a lung and the shape sensing includes
optical shape sensing. The pre-operative images are obtained by computed tomography (CT) although other imaging methods may be employed. A global structure of airways of the lungs is extracted from the pre-operative images, and a path that is supposed to be chosen to reach a target is computed by pathway determination module 144. This path provides information about which path is supposed to be taken by the physician - thus limiting the possibilities where the bronchoscope can be.

Referring to FIG. 2, in one embodiment, the result of the shape sensing data and the compensated imaging data may generate centerlines to provide points of comparison. FIG. 2 depicts a bronchial tree 202 to be navigated during a procedure. The tree 202 includes many airways 204 that need to be navigated to reach a target 206. By the present principles, two centerlines are made available. One centerline 208 has its path measured by the shape sensing component while another centerline 210 is computed from a pre-operative image, such as a CT image, an MRI image, a fluoroscopy image, etc. These two centerlines 208 and 210 can now be compared. Based on the measured and the expected shape, a path selected by a physician can be verified. This path is modeled by the centerline 208 generated by the shape sensing data.

Characteristic points can be extracted (e.g., points at locations with very high curvature that belong to bifurcations). These points provide reference points to permit better verification as the patient breathes during the intervention. Based on these reference points, information is provided to the physician as to which direction to select at a next branching or bifurcation point. For example, a tip of the bronchoscope or other instrument is tracked to provide its current location so that a virtual rendering can be adapted and assist in decision making for which direction to take at a next decision point (e.g., a trachea bifurcation 212). For example, it can be extracted that the tip of the bronchoscope is 3 mm after the trachea. Thus, the virtual image can be adapted with respect to that information.

Having the two centerlines 208 and 210 permits motion compensation for local warping between an extracted airway tree and a measured shape. This can be employed to again adapt the virtual rendering or compensate motion locally. Local motion or warping may be as a result of physical changes such as blood flow, heart beat, breathing, etc., or from other sources, e.g., fusing images from two or more different sources, such as CT/X-Ray fusion, or local warping due to instrument presence. Local warping can also help to verify if the right path has been chosen. For example, bronchial segmentation (and thus the calculated path) can be locally warped according to a deformation field obtained from shape sensing measured centerlines (e.g., before and after deformation). Afterwards, a path can be verified to determine whether the computed path and the measured path match.

Referring to FIG. 3, bronchial tree systems 300 and 301 are illustratively depicted, respectively for an inhale state and an exhale state. A measured path 306 for the exhale is overlaid on a bronchial tree image 302, and a measured path 308 for the inhale is overlaid on a bronchial tree image 304. From the two measurements 306 and 308, deformation can be computed. Registration of the measure paths 306 and 308 with each of the images 302 and 304 indicates whether the desired path was navigated since the data can be verified multiple times.

It should be understood that local motion compensation is usually sufficient, as the main interest is usually on an area around the calculated path where the target is located. Thus, e.g., local motion compensation is sufficient in a left main bronchus, while a right main bronchus is not of interest.

Referring to FIG. 4, a method for shape sensing assistance in a medical procedure is illustratively shown in accordance with one embodiment. In block 402, a three-dimensional (3D) image of a distributed pathway system is provided. The 3D images may be created by segmenting CT images or images gathered through other systems or technologies (e.g., MRI, X-ray, etc.). The images may be processed for motion compensation or other corrections in block 404. The motion compensation may employ information from shape sensing.

In block 406, a shape sensing enabled elongated device is introduced into the pathway system. The pathway system may include a lung, a blood vessel, the heart, etc. The elongated device may include a catheter, guide wire, bronchoscope, etc. The shape sensing is preferably performed using an optical fiber shape sensing system although other shape sensing devices may be employed.

In block 408, the elongated device is preferably registered with the three-dimensional image. This may be performed using a tracking system (e.g., EM), physical guide posts or other registration methods. In block 410, a shape of the elongated device is measured in the pathway system. The measuring of the shape may include measuring a first shape of the elongated device in a first state and a second shape of the elongated device in a deformed state in block 412. By measuring the shape in different states (e.g., inhale/exhale, etc.), additional data is collected to increase the level of confidence in evaluating the correct pathways being navigated.

In block 414, the shape with the three-dimensional image is compared to determine whether a given path has been selected relative to a target. The target may include a lesion or other object of the procedure. In block 416, the comparison may include first generating geometric representations of the shape(s) and the three-dimensional images. In this way, the geometric representations may be compared. The geometric representations may include, e.g., centerlines, boundary lines, points of interest, etc. In block 418, when measuring the shapes in different states, a comparison between first and second shapes (e.g., inhale/exhale) to corresponding three-dimensional images may be performed to de-
termine whether a correct path has been selected relative to the target.

[0037] In block 420, when an incorrect path has been selected, an indication of such may be made to the physician. The indication may include a warning of an imminent incorrect selection, a display of a location where the incorrect path was selected, and/or a visual or audible indication that the incorrect path was selected. In block 422, the process is repeated if necessary for each new decision. In block 424, the procedure is carried out with respect to the target.

[0038] In interpreting the appended claims, it should be understood that:

a) the word "comprising" does not exclude the presence of other elements or acts than those listed in a given claim;
b) the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements;
c) any reference signs in the claims do not limit their scope;
d) several "means" may be represented by the same item or hardware or software implemented structure or function; and

e) no specific sequence of acts is intended to be required unless specifically indicated.

[0039] Having described preferred embodiments for systems and methods for shape sensing assisted medical procedures (which are intended to be illustrative and not limiting), it is noted that modifications and variations can be made by persons skilled in the art in light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments of the disclosure disclosed which are within the scope of the embodiments disclosed herein as outlined by the appended claims.

Claims

1. A system for assistance in a medical procedure, comprising:

   one or more processors (114);
a memory (116) coupled to the one or more processors (114) and configured to store:
   
a three-dimensional image (111) of a distributed pathway system (148); and
   a pathway determination module configured to compute paths in the three-dimensional image; and
   a shape sensing enabled elongated device (102) configured for insertion into the pathway system and configured to measure a shape of the elongated device in the pathway system; and

   characterized in that

   the pathway determination module (144) is further configured to repeatedly compare the measured shape with the paths in the three-dimensional image to determine and indicate whether a given path has been selected relative to a target.

2. The system as recited in claim 1, wherein the pathway determination module (144) generates a first geometric representation of the shape and a second geometric representation of the three-dimensional image and compares the first geometric representation with the second geometric representation.

3. The system as recited in claim 2, wherein the first geometric representation and the second geometric representation include centerlines (208, 210).

4. The system as recited in claim 1, wherein the system is arranged to measure the shape in a first state (300) and in a deformed state (301).

5. The system as recited in claim 1, further comprising a warning mechanism (146) configured to indicating that an incorrect path has been selected.

6. The system as recited in claim 1, wherein the three-dimensional image (111) includes a motion-compensated three-dimensional image.

Patentansprüche

1. System zur Unterstützung bei einem medizinischen Verfahren, umfassend:

   einen oder mehrere Prozessoren (114);
en einen mit dem einen oder den mehreren Prozessoren (114) gekoppelten Speicher (116), der ausgelegt ist:

   um ein dreidimensionales Bild (111) eines verteilten Wegesystems (148) zu speichern; und
   ein Wegbestimmungsmodul, das ausgelegt ist, um Wege im dreidimensionalen Bild zu berechnen; und
   eine längliche Vorrichtung mit aktivierter Formerkennung (102), die ausgelegt ist für die Einführung in das Wegesystem, und die ausgelegt ist zum Messen einer Form der länglichen Vorrichtung im Wegesystem; und

dadurch gekennzeichnet, dass

   das Wegbestimmungsmodul (144) weiter ausgelegt ist, um wiederholt die gemessene
Form mit den Wegen im dreidimensionalen Bild zu vergleichen, um zu bestimmen und anzuzeigen, ob ein gegebener Weg im Verhältnis zu einem Ziel ausgewählt worden ist.

2. System nach Anspruch 1, wobei das Wegbestimmungsmodul (144) eine erste geometrische Darstellung der Form erzeugt und eine zweite geometrische Darstellung des dreidimensionalen Bilds erzeugt und die erste geometrische Darstellung mit der zweiten geometrischen Darstellung vergleicht.

3. System nach Anspruch 2, wobei die erste geometrische Darstellung und die zweite geometrische Darstellung Mittellinien (208, 210) enthalten.

4. System nach Anspruch 1, wobei das System angeordnet ist, um die Form in einem ersten Zustand (300) und in einem verformten Zustand (301) zu messen.

5. System nach Anspruch 1, weiter umfassend einen Warnmechanismus (146), der ausgelegt ist, um anzuzeigen, dass ein falscher Weg gewählt worden ist.

6. System nach Anspruch 1, wobei das dreidimensionale Bild (111) ein bewegungskompensiertes dreidimensionales Bild enthält.

Revendications

1. Système d’assistance dans une procédure médicale, comprenant :

   un ou plusieurs processeurs (114) ;
   une mémoire (116) couplée aux un ou plusieurs processeurs (114) et configurée pour stocker :

   une image tridimensionnelle (111) d’un système de voies distribuées (148) ; et
   un module de détermination de voies configuré pour calculer des voies dans l’image tridimensionnelle ; et
   un dispositif allongé validé en détection de forme (102) configuré pour une insertion dans le système de voies et configuré pour mesurer une forme du dispositif allongé dans le système de voies ; et
   caractérisé en ce que :

le module de détermination de voies (144) est en outre configuré pour comparer de manière répétée la forme mesurée avec les voies de l’image tridimensionnelle afin de déterminer et d’indiquer si une voie donnée a ou non été sélectionné par rapport à une cible.

2. Système selon la revendication 1, dans lequel le module de détermination de voies (144) génère une première représentation géométrique de la forme et une seconde représentation géométrique de l’image tridimensionnelle et compare la première représentation géométrique à la seconde représentation géométrique.

3. Système selon la revendication 2, dans lequel la première représentation géométrique et la seconde représentation géométrique incluent des axes centraux (208, 210).

4. Système selon la revendication 1, dans lequel le système est agencé pour mesurer la forme dans un premier état (300) et dans un état déformé (301).

5. Système selon la revendication 1, comprenant en outre un mécanisme d’avertissement (146) configuré pour indiquer qu’une voie incorrecte a été sélectionnée.

6. Système selon la revendication 1, dans lequel l’image tridimensionnelle (111) inclut une image tridimensionnelle compensée en mouvement.
FIG. 1
Provide a 3D image of pathway system

Process 3D image (e.g., motion compensation)

Introduce shape sensing device into pathway system

Register shape sensing device with 3D image

Measure shape of device in pathway system

Measure shape for different (e.g., deformed) states

Compare shape with 3D image

Generate geometric representations

For different measured states, compare the different states

Indicate when an incorrect path is selected

Repeat steps until target achieved

Perform procedure on target

FIG. 4
REFERENCES CITED IN THE DESCRIPTION

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