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(54) REAL-TIME DEPTH ESTIMATION FROM MONOCULAR ENDOSCOPE IMAGES

ECHTZEIT-TIEFENSCHÄTZUNG AUS MONOKULAREN ENDOSKOPBILDERN

ESTIMATION DE LA PROFONDEUR EN TEMPS RÉEL À PARTIR D'IMAGES ENDOSCOPIQUES MONOCULAIRES

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(56) References cited:
EP-A1- 2 030 558
WO-A1-2008/032230
WO-A2-2007/008289
US-A1- 2002 156 345
US-A1- 2009 048 482
US-A1- 2009 088 634

- **BUXTON BF AND BUXTON H: "Monocular Depth Perception from Optical Flow by Space Time Signal Processing", BIOLOGICAL SCIE, PROCEEDINGS OF THE ROYAL SOCIETY B, vol. 218, 22 April 1983 (1983-04-22), pages 27-47, XP008176815, ISSN: 0962-8452, DOI: 10.1098/RSPB.1983.0024**
- **P. BARALDI ET AL: "Motion and Depth from Optical Flow", PROCEDINGS OF THE ALVEY VISION CONFERENCE 1989, 1 January 1989 (1989-01-01), pages 35.1-35.4, XP055198413, DOI: 10.5244/C.3.35**
- **HEEGER D J ET AL: "Simple method for computing 3D motion and depth", PROCEEDINGS / THIRD INTERNATIONAL CONFERENCE ON COMPUTER VISION : DECEMBER 4 - 7, 1990, OSAKA, JAPAN; [PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON COMPUTER VISION], IEEE COMPUTER SOC. PRESS, LOS ALAMITOS, CALIF, vol. CONF. 3, 4 December 1990 (1990-12-04) , pages 96-100, XP010020037, DOI: 10.1109/ICCV.1990.139502 ISBN: 978-0-8186-2057-7**

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Description

[0001] The present invention generally relates to minimally invasive surgeries involving an endoscope. The present invention specifically relates to estimating real-time depth of objects shown in images obtained from an endoscope.

[0002] Generally, a minimally invasive surgery utilizes an endoscope, which is a long, flexible or rigid tube having an imaging capability. Upon insertion into a body through a natural orifice or a small incision, the endoscope provides image of the region of interest that may be viewed through an eyepiece or on a screen as a surgeon performs the operation. Essential to the surgery is the depth information of object(s) within the images that will enable the surgeon to be able to advance the endoscope while avoiding the object(s) and will facilitate a real-time tracking position of the endoscope. However, the frames of an endoscopic image are two-dimensional and the surgeon therefore may lose the perception of the depth of object(s) viewed in the screen shoot of the images. A common solution to that problem is the use of stereo endoscopic imaging and surgical tool tracking, such as described in Patent Application No. US 2009/0088634 A1.

[0003] The present invention, in contrary, provides a technique that utilizes endoscopic video frames from the monocular endoscopic images to generate a depth map despite the two-dimensional limitation of the endoscopic video frames.

[0004] One form of the present invention, the scope of which is defined by independent claim 1, is a minimally invasive surgical system employing an endoscope and an endoscopic surgical control unit. In operation, the endoscope generates a plurality of endoscopic video frames as the endoscope is advanced to a target location within an anatomical region of a body with the endoscopic video frames illustrating a monocular endoscopic images of the anatomical region. For real-time estimation of a depth of an object within monocular endoscopic images (e.g., shape of a bronchial wall within monocular endoscopic images of a bronchial tube), the endoscopic surgical control unit receives the endoscopic video frames as the endoscope is advanced to the target location to estimate a depth field indicative of a depth of the object within the monocular endoscopic images of the anatomical region as a function of an optical flow of the image point(s) within a frame time series of the monocular endoscopic images of the anatomical region.

FIG. 1. illustrates an exemplary embodiment of a minimally invasive surgical system in accordance with the present invention.
FIG. 2 illustrates a flowchart representative of an example of a depth estimation method using a system of the present invention.
FIG. 3 illustrates a flowchart representative of a first example of the depth estimation method illustrated in FIG. 2 in using a system of the present invention.
FIG. 4 illustrates an exemplary application of the flowchart illustrated in FIG. 3.
FIG. 5 illustrates an exemplary optical flow as known in the art.
FIG. 6 illustrates an exemplary depth field as known in the art.
FIG. 7 illustrates an exemplary depth map as known in the art.
FIG. 8 illustrates a flowchart representative of a second example of the depth estimation method illustrated in FIG. 2.

[0005] As shown in FIG. 1, a minimally invasive surgical system 10 of the present invention employs an endoscope 20 and a endoscopic surgical control unit 30.

[0006] Endoscope 20 is broadly defined herein as any device structurally configured for internally imaging an anatomical region of a body (e.g., human or animal) via fiber optics, lenses, miniaturized (e.g. CCD based) imaging systems or the like. Examples of endoscope 20 include, but are not limited to, any type of scope (e.g., a bronchoscope, a colonoscope, a laparoscope, etc.) and any device similar to a scope that is equipped with an image system (e.g., an imaging cannula).

[0007] An external imaging device 31 of unit 30 is broadly defined herein as any device structurally configured for externally imaging an anatomical region of a body. Examples of external imaging device 31 include, but are not limited to, a computer tomography device, a magnetic resonance imaging device, an ultrasound device and an x-ray device.

[0008] An endoscopic path planning device 32 of unit 30 is broadly defined herein as any device structurally configured for pre-operatively planning a kinematic path to reach a target location within an anatomical region of a body for purposes of configuring endoscope 20 (e.g., configuring an imaging cannula) and/or for purposes of controlling endoscope 20 in reaching the target location (e.g., operating the controls of a bronchoscope). In the context of endoscope 20 being a bronchoscope or a kinematically similar scope, a path planning technique taught by International Application WO 2007/042986 A2 to Trovato et al. published April 17, 2007, and entitled "3D Tool Path Planning, Simulation and Control System" may be used by device 32 to generate a kinematically correct path for endoscope 20 within the anatomical region of the body (e.g., lungs) as indicated by a 3D dataset of the anatomical region as acquired by external imaging device 31. In the context of endoscope 20 being an imaging nested cannula or a kinematically similar device, the path planning/nested cannula configuration technique taught by International Application WO 2008/032230 A1 to Trovato et al. published March 20, 2008, and entitled "Active Cannula Configuration For Minimally Invasive Surgery" may be used by device 32 to generate a kinematically correct configuration for endoscope 20 for reaching the target location within the anatomical region of the body (e.g., lungs) as indicated by a 3D dataset of the anatomical region as acquired by external imaging device 31.

[0009] An endoscopic tracking device 33 of unit 30 is broadly defined herein as any device structurally configured for tracking a position of endoscope 20 within an anatomical region of a body. One example of endoscopic tracking device 33 is the optical tracking device taught by U.S. Patent No. 6,135,946 to Konen et al. issued October 4, 2004, and entitled "Method and System for Image-Guided Interventional Endoscopic Procedures". A further example of endoscopic tracking device 33 is any commercially available electromagnetic tracking unit, such as, for example, the electromagnetic tracking unit commercially available as the inReach™ system from superDimension, Inc.

[0010] Depth estimation device 34 of unit 30 is broadly defined herein as any device structurally configured for estimating a depth field from a pattern of actual motion of image points/features in a frame time series acquired by endoscope 20 (i.e., two or more images in accordance with any type of time sequence). In practice, depth estimation device 34 may be utilized by unit 30 for estimating a depth field to facilitate endoscopic path planning device 32 in generating a pre-operative configuration of endoscope 20 to reach a target location within an anatomical region and/or in generating a pre-operative plan of a kinematic path for controlling endoscope 20 in reaching the target location. Additionally, depth estimation device 34 may be utilized in practice by unit 30 for estimating a depth field to facilitate a registration of the endoscopic image from endoscope 20 with the pre-operative images acquired by device 31 and/or to enhance a real-time tracking of a position of endoscope 20 within the anatomical region as endoscope 20 is advanced to the target location. Further, in practice, depth estimation device 34 may operate independently of other devices from unit 30 or be internally incorporated within one of the other devices of unit 30.

[0011] Flowchart 40 as shown in FIG. 2 represents a depth estimation method of the present invention as executed by depth estimation device 34 (FIG. 1). For this method, depth estimation device 34 begins with a stage S41 of flowchart 40 to determine an optical flow of motion of image points/features in a frame time series of monocular endoscopic images acquired by endoscope 20. Subsequently or concurrently with the execution of stage S41, depth estimation device 34 proceeds to a stage S42 of flowchart 40 to estimate a depth field from the optical flow where the depth field indicates the depth of one or more objects in the monocular endoscopic images and the depth field estimation is utilized for the display of a depth map in a stage S43 of flowchart 40.

[0012] Flowchart 50 as shown in FIG. 3 represents an exemplary embodiment of flowchart 40 (FIG. 2). Specifically, the determination of the optical flow by device 34 involves a generation of a vector field including a plurality of vectors during a stage S52 of flowchart 50 with each vector representing a motion of a particular image point within the monocular endoscopic images (e.g., between two monocular endoscopic images). For example, as shown in FIG. 4, an optical flow of motion of image points/features for each endoscopic video frame in a frame time series 22 of bronchial tubes 61 of a patient 60 taken by endoscope 20 as endoscope 20 traverses an endoscopic path 21 within bronchial tubes 61 may be determined by vectors representing a motion of image points within the monocular endoscopic images (e.g., a vector field 70 as shown in FIG. 5).

[0013] Furthermore, a velocity of endoscope 20 between two endoscopic video frames may be computed from relative positions of endoscope 20 for the given frames as tracked by endoscopic tracking device 33. The frames may be consecutive or at some delay in view of an assumption of a stationary object being observed by endoscope 20 between frames. Given the velocity of endoscope 20, a depth field may be estimated from a point on the optical flow that is not moving in consecutive slices that is known as a focus of expansion ("FOE") in view of the fact that an optical axis of endoscope 20 is aligned with its movement and therefore the FOE is aligned with the movement of endoscope 20. Depth information for each point may be computed by knowing (1) a distance D of every point from the FOE as identified by a stage S52 of flowchart 50, (2) an amplitude V of optical flow in every point and (3) a velocity v of endoscope 20. Specifically, depth estimation device 34 computes depth information for each image point during a stage S53 of flowchart 50 in accordance with the following equation [1]:

$$Z = v * D / V \qquad [1]$$

where Z is depth of an image point. In this case, the X and Y positions may be computed from intrinsic parameters of endoscope 20 (e.g., a focal point, etc).

[0014] For example, as shown in FIG. 4, endoscopic tracking device 33 provides tracking data 35 to depth estimation device 34 that enables depth estimation device 34 to determine the velocity v of endoscope 20 in generating frame time series 23. As such, based on knowing the distance D of every image point from the identified FOE in the vector field and an amplitude V of optical flow in every point, depth estimation device 34 computes the Z depth for each point within a computed vector field of frame time series 23 to estimate a depth field 36 (e.g., a depth field 71 shown in FIG. 6) and to generate a depth map 37 (e.g., color coded depth field 72 shown in FIG. 7).

[0015] Flowchart 80 as shown in FIG. 8 represents an alternative embodiment of flowchart 40 (FIG. 2). Flowchart 80 is based on a stereoscopic vision of two views of the same scene (i.e., two endoscopic video frames taken at slightly different time). Specifically, upon generation of the vector field during a stage S81 of flowchart 80 and given that the endoscope 20 is being tracked by device 33, relative positions of endoscope 20 for two views are also known. For this case, a coordinate system is attached to the camera pose creating the first view. Therefore, a known pose that generated the second view relative to the first view is defined with 3x3 rotation matrix R and 3x1 translation vector t. Furthermore, a camera intrinsic 3x3 matrix K may be defined given that intrinsic camera parameters of endoscope 20 are known (e.g., from a camera datasheet or from a known calibration method). From these data, a stage S82 of flowchart 80 involves a computation of 4x4 projection matrices for the first view P1 and the second view P2 in accordance with the following equations [2] and [3]:

$$P_1 = [I \mid 0] \qquad [2]$$

$$P_2 = K*[R|T]*K^{-1} \qquad [3]$$

[0016] A stage S83 of flowchart 80 involves a geometric triangulation of the projection elements of the projection matrices to compute the depth of each image point.

[0017] If endoscope 20 is not tracked by device 33, a similar procedure may be performed using the vector field to estimate projection matrices. In this case, the depth would be estimated to a scale factor only, real physical depth would not be known.

[0018] Although the present invention has been described with reference to exemplary aspects, features and implementations, the disclosed systems and methods are not limited to such exemplary aspects, features and/or implementations, and the scope of protection of the present invention is entirely defined by the appended claims.

Claims

1. A minimally invasive surgical system (10), comprising:

an endoscope (20) for generating a plurality of endoscopic video frames (22) as the endoscope (20) is advanced to a target location within an anatomical region of a body, the endoscopic video frames (22) illustrating monocular endoscopic images of the anatomical region; and
an endoscopic surgical control unit (30) in communication with the endoscope (20) to receive the endoscopic video frames (22) as the endoscope (20) is advanced to the target location,
wherein the endoscopic surgical control unit (30) is operable to

track positions of the endoscope (20) within the anatomical region as the endoscope (20) is advanced to the target location within the anatomical region,
determine a velocity of the endoscope (20) in a frame time series (23) from the tracked positions,
determine an optical flow by (S51) generating a vector field including a plurality of vectors, each vector indicative of a motion of one of the image points within the frame time series, and
estimate a depth field (36) indicative of a depth of an object within the monocular endoscopic images of the anatomical region as a function of the optical flow of at least one image point within the frame time series of the monocular endoscopic image of the anatomical region and the determined velocity.

2. The minimally invasive surgical system (10) of claim 1, wherein the endoscopic surgical control unit (30) is further operable to generate a depth map display (37) representative of a depth field estimation.

3. The minimally invasive surgical system (10) of claim 1, wherein the endoscopic surgical control unit (30) is further operable to register the monocular endoscopic images with a pre-operative image of the anatomical region of the body as a function of the depth field estimation.

4. The minimally invasive surgical system (10) of claim 1, wherein the endoscopic surgical control unit (30) is further operable to pre-operatively plan a kinematic path (21) for the endoscope (20) to reach the target location within the anatomical region.

5. The minimally invasive surgical system (10) of claim 1, wherein a generation of the optical flow of the at least one image point within the frame time series of the monocular endoscopic images of the anatomical region includes a tracking of the positions of the endoscope (20) within the anatomical region.

6. The minimally invasive surgical system (10) of claim 1, wherein the endoscope (20) is one of a group including a bronchoscope and a nested cannula.

7. The minimally invasive surgical system of claim 1, wherein the endoscopic surgical control unit (30) is operable to estimate the depth field by:

    (S52) identifying a focus of expansion within the vector field; and
    (S53) computing a depth point for each image point as a function of a distance of each image point from the focus of expansion.

8. The minimally invasive surgical system of claim 1, wherein the endoscopic surgical control unit (30) is operable to estimate the depth field by:
(S53) computing a depth point for each image point as a function of an amplitude of each vector in the vector field.

9. The minimally invasive surgical system of claim 1, wherein the endoscopic surgical control unit (30) is operable to estimate the depth field by:
(S53) computing a depth point for an image point as a function of a velocity of each vector in the vector field.

10. The minimally invasive surgical system of claim 1, wherein the endoscopic surgical control unit (30) is operable to estimate the depth field by:
(S82) computing projection matrices as a function of the vector field.

11. The minimally invasive surgical system of claim 10, wherein the endoscopic surgical control unit (30) is operable to estimate the depth field by:
(S83) computing a depth point for each image point as a function of a geometric triangulation of projection elements of the projection matrices.

Patentansprüche

1. Minimalinvasives chirurgisches System (10), umfassend:

    ein Endoskop (20) zum Erzeugen einer Vielzahl endoskopischer Videoframes (22), wenn das Endoskop (20) zu einer Zielstelle innerhalb einer anatomischen Region eines Körpers vorgeschoben wird, wobei die endoskopischen Videoframes (22) monokulare endoskopische Bilder der anatomischen Region veranschaulichen; und
    eine endoskopische chirurgische Steuerungseinheit (30) in Verbindung mit dem Endoskop (20), um die endoskopischen Videoframes (22) zu empfangen, wenn das Endoskop (20) zu der Zielstelle vorgeschoben wird, wobei die endoskopische chirurgische Steuerungseinheit (30) betriebsbereit ist, um
    Positionen des Endoskops (20) innerhalb der anatomischen Region nachzuverfolgen, wenn das Endoskop (20) zu der Zielstelle innerhalb der anatomischen Region vorgeschoben wird,
    eine Geschwindigkeit des Endoskops (20) innerhalb einer Frame-Zeitreihe (23) von den nachverfolgten Positionen zu bestimmen,
    einen optischen Fluss durch (S51) Erzeugen eines Vektorfeldes, beinhaltend eine Vielzahl von Vektoren, zu bestimmen, wobei jeder Vektor für eine Bewegung eines der Bildpunkte innerhalb der Frame-Zeitreihe indikativ ist, und
    eine Schärfentiefe (36), die für eine Tiefe eines Objekts innerhalb der monokularen endoskopischen Bilder der anatomischen Region indikativ ist, als Funktion des optischen Flusses mindestens eines Bildpunktes innerhalb der Frame-Zeitreihe des monokularen endoskopischen Bildes der anatomischen Region und der bestimmten Geschwindigkeit zu schätzen.

2. Minimalinvasives chirurgisches System (10) nach Anspruch 1, wobei die endoskopische chirurgische Steuerungseinheit (30) weiter betriebsbereit ist, um eine Tiefenkartenanzeige (37) zu erzeugen, die für eine Schärfentiefeschätzung repräsentativ ist.

3. Minimalinvasives chirurgisches System (10) nach Anspruch 1, wobei die endoskopische chirurgische Steuerungseinheit (30) weiter betriebsbereit ist, um die monokularen endoskopischen Bilder mit einem präoperativen Bild der anatomischen Region des Körpers als Funktion der Schärfentiefeschätzung zu registrieren.

4. Minimalinvasives chirurgisches System (10) nach Anspruch 1, wobei die endoskopische chirurgische Steuerungseinheit (30) weiter betriebsbereit ist, um präoperativ einen kinematischen Weg (21) zu planen, damit das Endoskop (20) die Zielstelle innerhalb der anatomischen Region erreicht.

5. Minimalinvasives chirurgisches System (10) nach Anspruch 1, wobei eine Erzeugung des optischen Flusses des mindestens einen Bildpunktes innerhalb der Frame-Zeitreihe der monokularen endoskopischen Bilder der anatomischen Region ein Nachverfolgen der Positionen des Endoskops (20) innerhalb der anatomischen Region beinhaltet.

6. Minimalinvasives chirurgisches System (10) nach Anspruch 1, wobei das Endoskop (20) eines einer Gruppe ist, die ein Bronchoskop und eine verschachtelte Kanüle beinhaltet.

7. Minimalinvasives chirurgisches System nach Anspruch 1, wobei die endoskopische chirurgische Steuerungseinheit (30) betriebsbereit ist, um die Schärfentiefe durch Folgendes zu schätzen:

(S52) Identifizieren eines Expansionsfokus innerhalb des Vektorfeldes und
(S53) Berechnen eines Tiefenpunktes für jeden Bildpunkt als Funktion eines Abstands jedes Bildpunktes von dem Expansionsfokus.

8. Minimalinvasives chirurgisches System nach Anspruch 1, wobei die endoskopische chirurgische Steuerungseinheit (30) betriebsbereit ist, um die Schärfentiefe durch Folgendes zu schätzen:
(S53) Berechnen eines Tiefenpunktes für jeden Bildpunkt als Funktion einer Amplitude jedes Vektors in dem Vektorfeld.

9. Minimalinvasives chirurgisches System nach Anspruch 1, wobei die endoskopische chirurgische Steuerungseinheit (30) betriebsbereit ist, um die Schärfentiefe durch Folgendes zu schätzen:
(S53) Berechnen eines Tiefenpunkts für einen Bildpunkt als Funktion einer Geschwindigkeit jedes Vektors in dem Vektorfeld.

10. Minimalinvasives chirurgisches System nach Anspruch 1, wobei die endoskopische chirurgische Steuerungseinheit (30) betriebsbereit ist, um die Schärfentiefe durch Folgendes zu schätzen:
(S82) Berechnen von Projektionsmatrizen als Funktion des Vektorfeldes.

11. Minimalinvasives chirurgisches System nach Anspruch 10, wobei die endoskopische chirurgische Steuerungseinheit (30) betriebsbereit ist, um die Schärfentiefe durch Folgendes zu schätzen:
(S83) Berechnen eines Tiefenpunktes für jeden Bildpunkt als Funktion einer geometrischen Triangulation von Projektionselementen der Projektmatrizen.

Revendications

1. Système chirurgical minimalement invasif (10), comprenant :

un endoscope (20) pour générer une pluralité de trames vidéo endoscopiques (22) lorsque l'endoscope (20) est avancé vers un emplacement cible dans une région anatomique d'un corps, les trames vidéo endoscopiques (22) illustrant des images endoscopiques monoculaires de la région anatomique ; et
une unité de commande chirurgicale endoscopique (30) en communication avec l'endoscope (20) pour recevoir les trames vidéo endoscopiques (22) lorsque l'endoscope (20) est avancé vers l'emplacement cible,
dans lequel l'unité de commande chirurgicale endoscopique (30) est opérationnelle pour
suivre des positions de l'endoscope (20) dans la région anatomique lorsque l'endoscope (20) est avancé vers l'emplacement cible dans la région anatomique,
déterminer une vitesse de l'endoscope (20) dans une série temporelle de trames (23) à partir des positions suivies,
déterminer un flux optique en (S51) générant un champ de vecteurs incluant une pluralité de vecteurs, chaque

vecteur indiquant un mouvement de l'un des points d'image dans la série temporelle de trames, et
estimer un champ de profondeur (36) indiquant une profondeur d'un objet dans les images endoscopiques monoculaires de la région anatomique en fonction du flux optique d'au moins un point d'image dans la série temporelle de trames de l'image endoscopique monoculaire de la région anatomique et la vitesse déterminée.

2. Système chirurgical minimalement invasif (10) selon la revendication 1, dans lequel l'unité de commande chirurgicale endoscopique (30) est en outre opérationnelle pour générer un affichage de carte de profondeur (37) représentatif d'une estimation de champ de profondeur.

3. Système chirurgical minimalement invasif (10) selon la revendication 1, dans lequel l'unité de commande chirurgicale endoscopique (30) est en outre opérationnelle pour enregistrer les images endoscopiques monoculaires avec une image préopératoire de la région anatomique du corps en fonction de l'estimation de champ de profondeur.

4. Système chirurgical minimalement invasif (10) selon la revendication 1, dans lequel l'unité de commande chirurgicale endoscopique (30) est en outre opérationnelle pour planifier de manière préopératoire un trajet cinématique (21) pour que l'endoscope (20) atteigne l'emplacement cible dans la région anatomique.

5. Système chirurgical minimalement invasif (10) selon la revendication 1, dans lequel une génération du flux optique du au moins un point d'image dans la série temporelle de trames des images endoscopiques monoculaires de la région anatomique inclut un suivi des positions de l'endoscope (20) dans la région anatomique.

6. Système chirurgical minimalement invasif (10) selon la revendication 1, dans lequel l'endoscope (20) est l'un d'un groupe incluant un bronchoscope et une canule emboîtée.

7. Système chirurgical minimalement invasif selon la revendication 1, dans lequel l'unité de commande chirurgicale endoscopique (30) peut être utilisée pour estimer le champ de profondeur en :

(S52) identifiant un foyer d'expansion dans le champ de vecteurs ; et
(S53) calculant un point de profondeur pour chaque point d'image en fonction d'une distance de chaque point d'image à partir du foyer d'expansion.

8. Système chirurgical minimalement invasif selon la revendication 1, dans lequel l'unité de commande chirurgicale endoscopique (30) est opérationnelle pour estimer le champ de profondeur en :
(S53) calculant un point de profondeur pour chaque point d'image en fonction d'une amplitude de chaque vecteur dans le champ de vecteurs.

9. Système chirurgical minimalement invasif selon la revendication 1, dans lequel l'unité de commande chirurgicale endoscopique (30) est opérationnelle pour estimer le champ de profondeur en :
(S53) calculant un point de profondeur pour un point d'image en fonction d'une vitesse de chaque vecteur dans le champ de vecteurs.

10. Système chirurgical minimalement invasif selon la revendication 1, dans lequel l'unité de commande chirurgicale endoscopique (30) peut être utilisée pour estimer le champ de profondeur en :
(S82) calculant des matrices de projection en fonction du champ de vecteurs.

11. Système chirurgical minimalement invasif selon la revendication 10, dans lequel l'unité de commande chirurgicale endoscopique (30) est opérationnelle pour estimer le champ de profondeur en :
(S83) calculant un point de profondeur pour chaque point d'image en fonction d'une triangulation géométrique d'éléments de projection des matrices de projection.

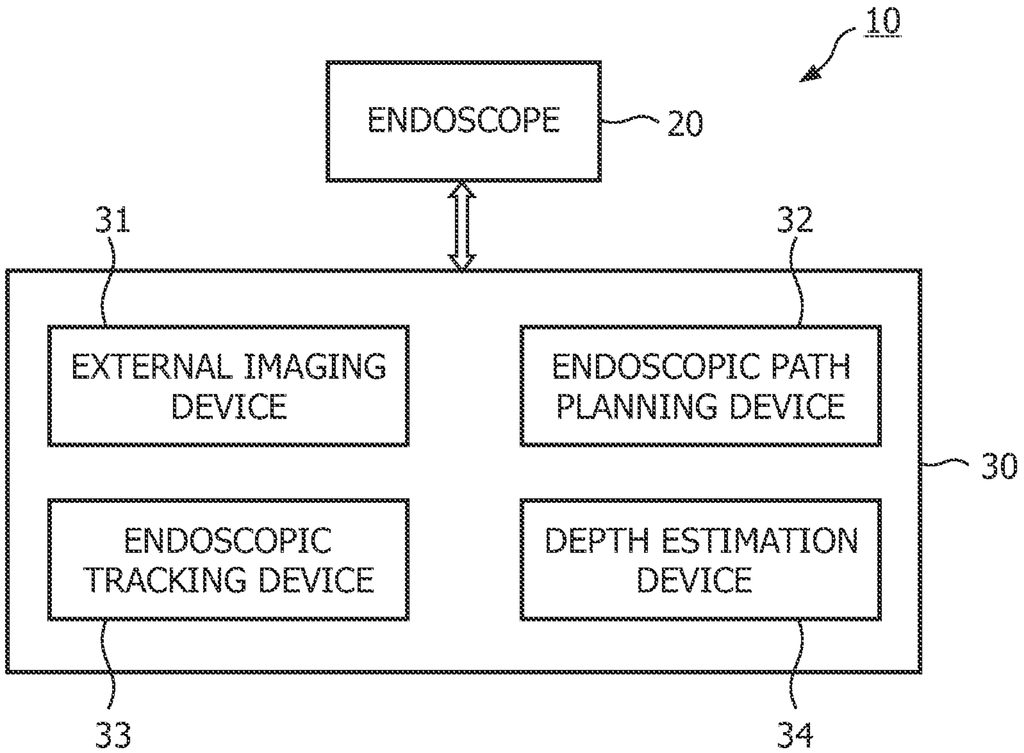
10
ENDOSCOPE
20
31
32
EXTERNAL IMAGING DEVICE
ENDOSCOPIC PATH PLANNING DEVICE
30
ENDOSCOPIC TRACKING DEVICE
DEPTH ESTIMATION DEVICE
33
34

FIG. 1

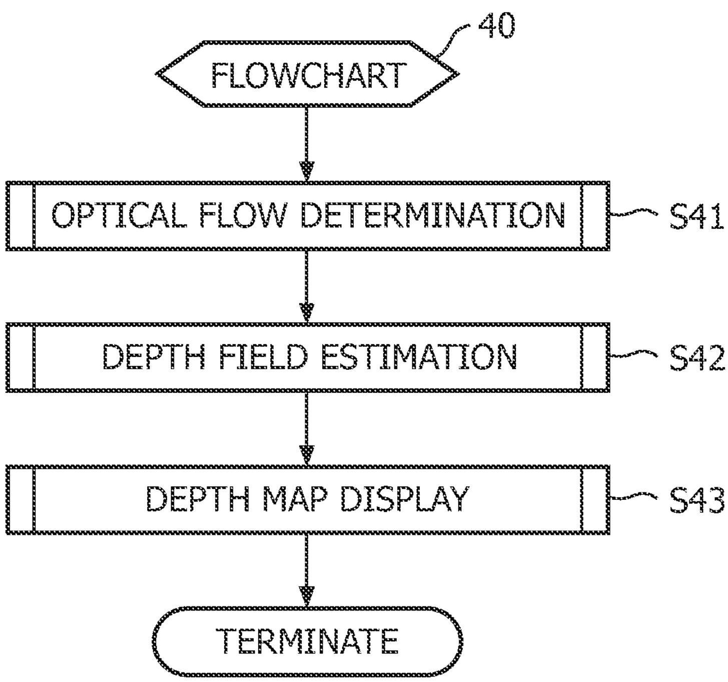
40
FLOWCHART
OPTICAL FLOW DETERMINATION
S41
DEPTH FIELD ESTIMATION
S42
DEPTH MAP DISPLAY
S43
TERMINATE

FIG. 2

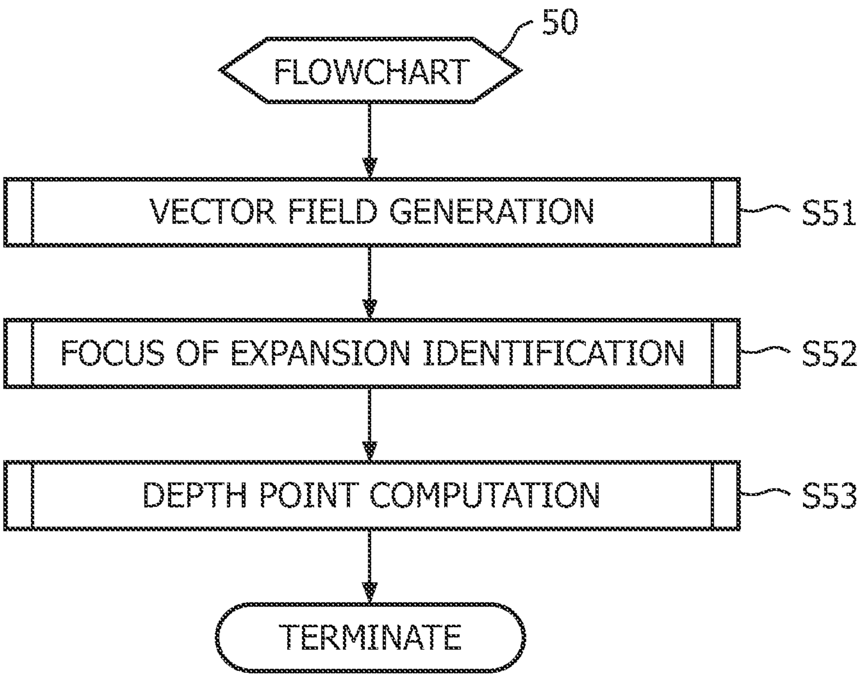
50
FLOWCHART
VECTOR FIELD GENERATION
S51
FOCUS OF EXPANSION IDENTIFICATION
S52
DEPTH POINT COMPUTATION
S53
TERMINATE

FIG. 3

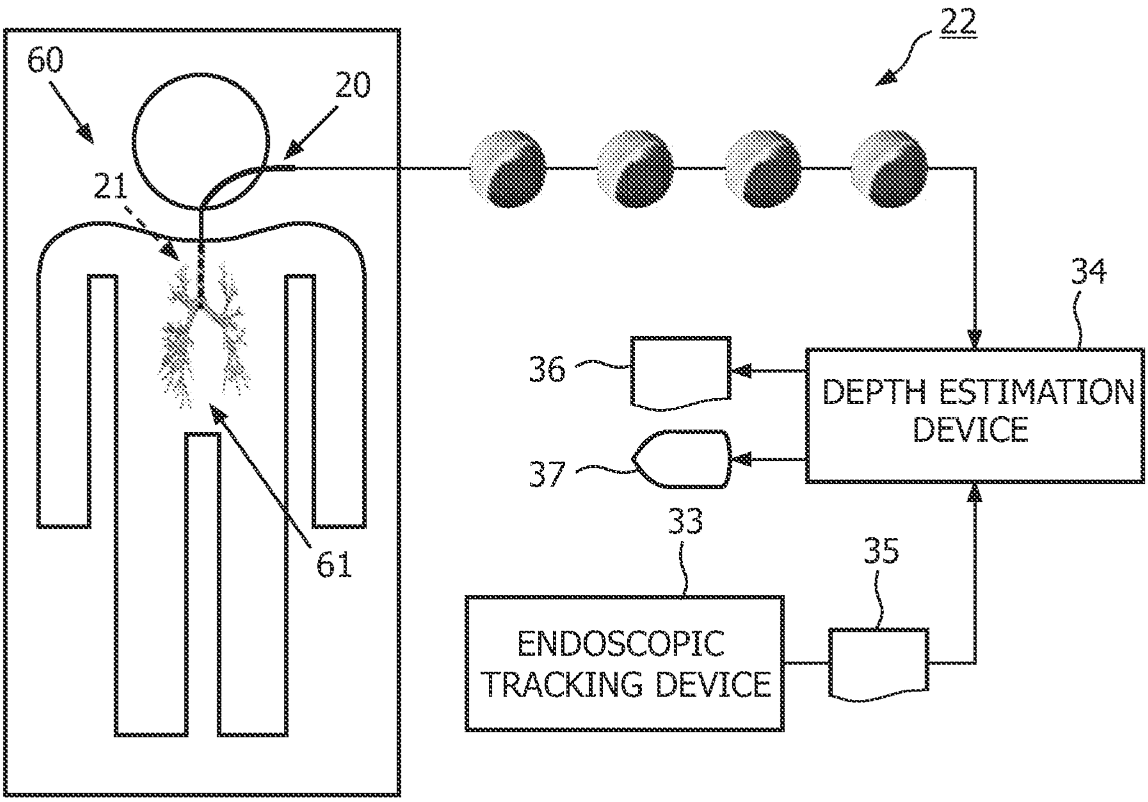
22
60
20
21
61
34
DEPTH ESTIMATION DEVICE
36
37
33
35
ENDOSCOPIC TRACKING DEVICE

FIG. 4

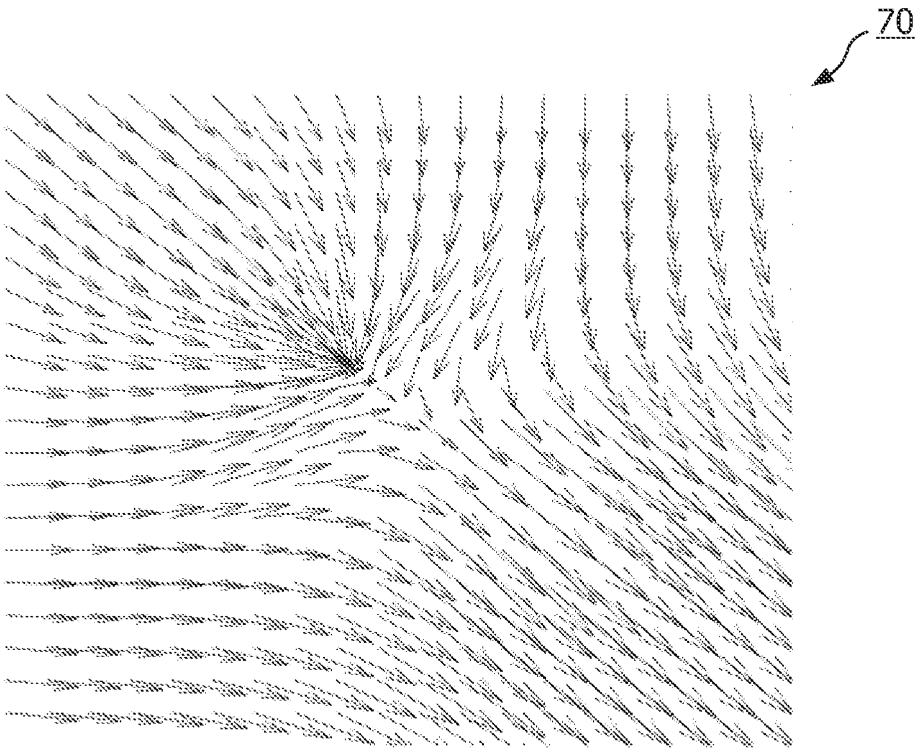

FIG. 5
(PRIOR ART)

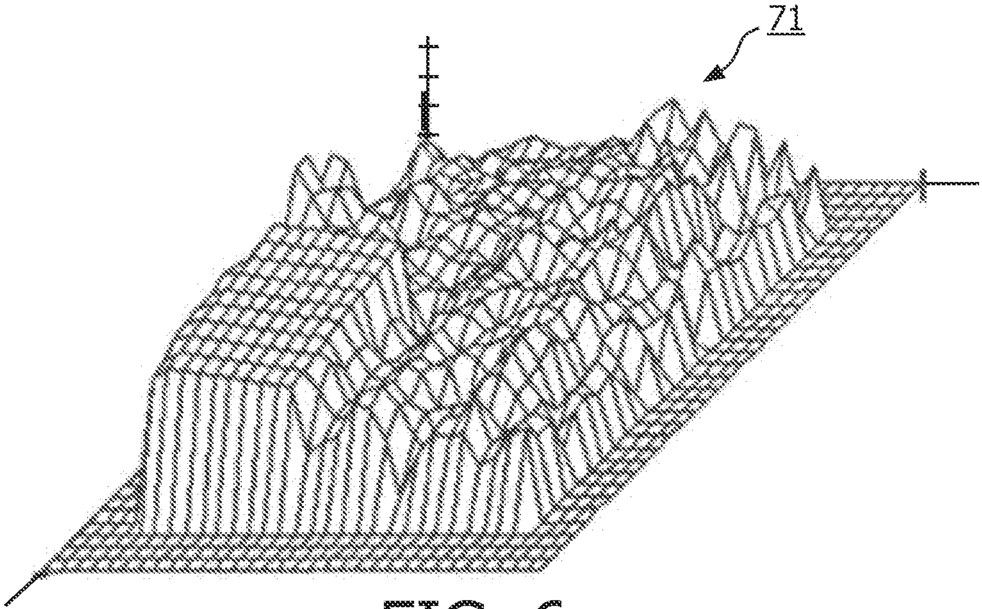

FIG. 6
(PRIOR ART)

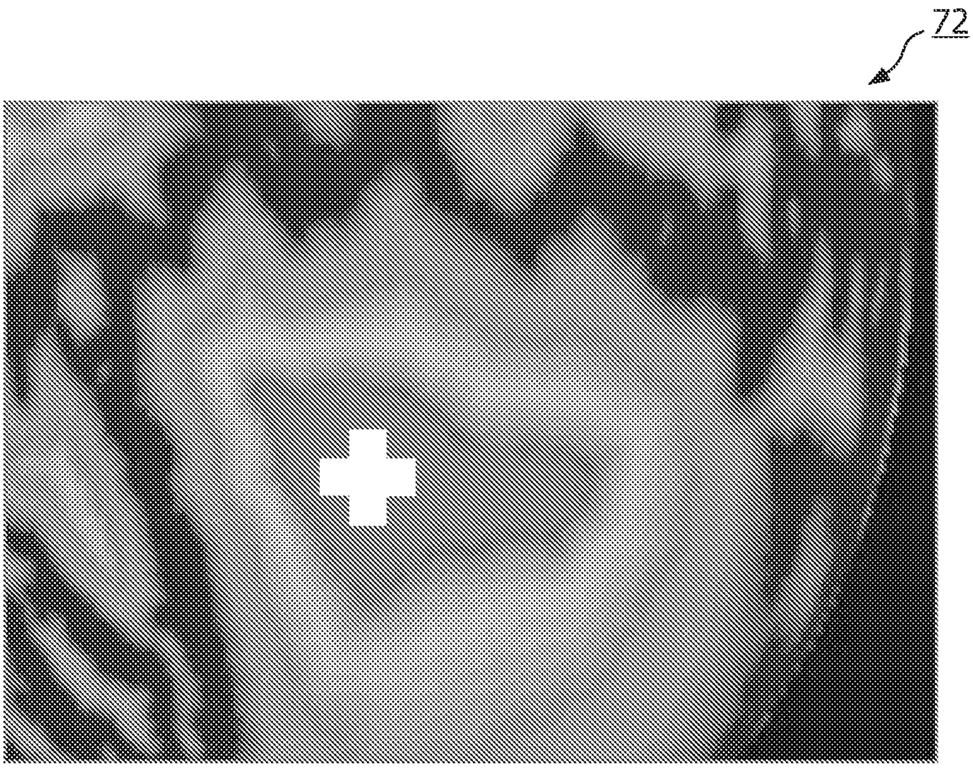

FIG. 7
(PRIOR ART)

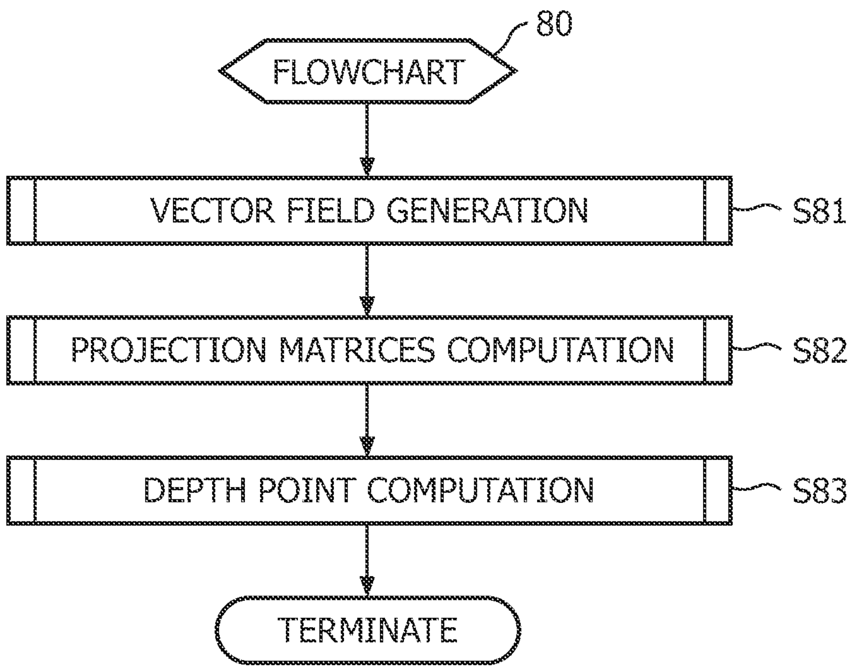

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20090088634 A1 **[0002]**
- WO 2007042986 A2, Trovato **[0008]**
- WO 2008032230 A1, Trovato **[0008]**
- US 6135946 A, Konen **[0009]**