



US 20040015053A1

(19) **United States**(12) **Patent Application Publication**
Bieger et al.(10) **Pub. No.: US 2004/0015053 A1**(43) **Pub. Date: Jan. 22, 2004**(54) **FULLY-AUTOMATIC, ROBOT-ASSISTED
CAMERA GUIDANCE USING POSITIONS
SENSORS FOR LAPAROSCOPIC
INTERVENTIONS**(30) **Foreign Application Priority Data**

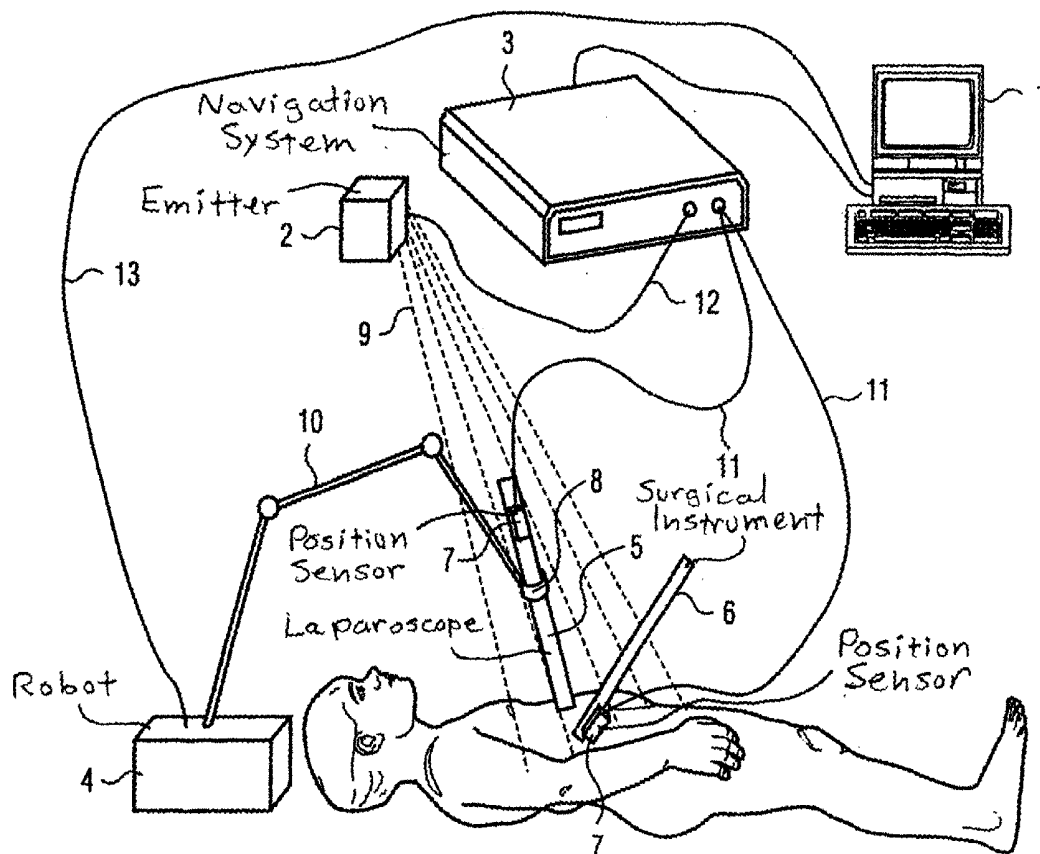
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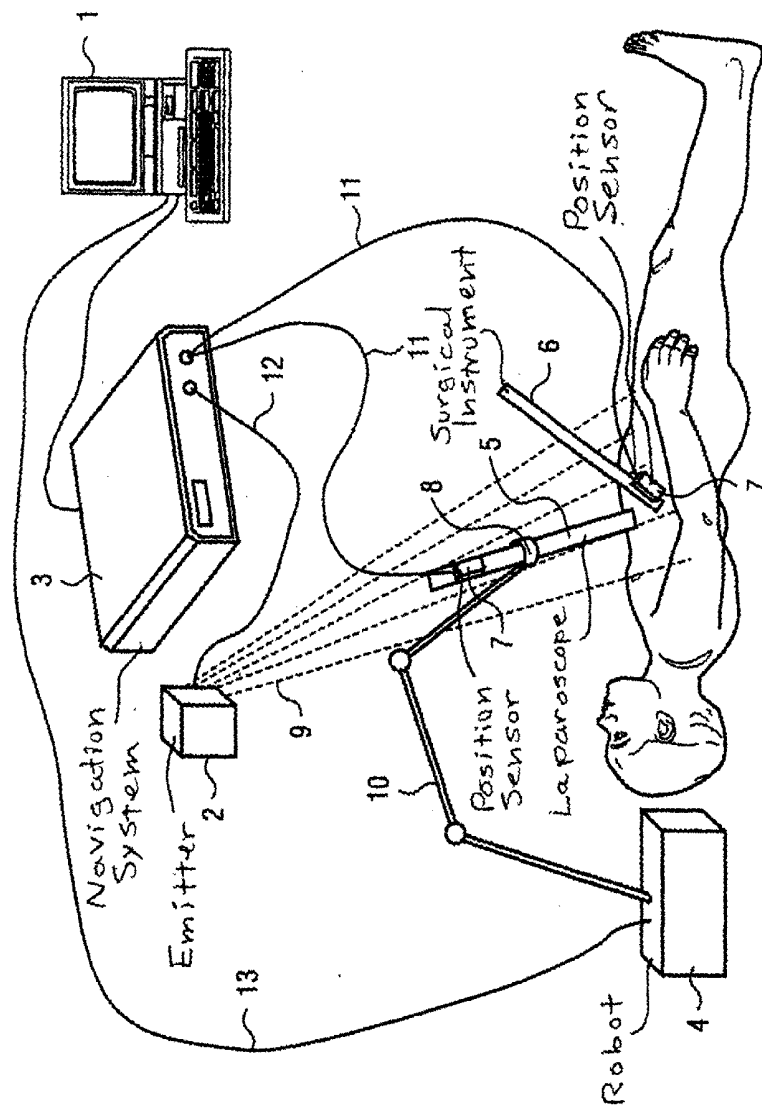
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(57) **ABSTRACT**

In a method and operating system for conducting a surgical intervention, respective position sensors are mounted at a laparoscope and a surgical instrument used to conduct the intervention, and a navigation system is supplied with orientation information from these position sensors. Based on this orientation information, the navigation system automatically controls a robot arm, to which the laparoscope is mounted, to always maintain the surgical instrument in the field of view of the laparoscope.

(21) **Appl. No.: 10/276,355**(22) **PCT Filed: May 17, 2001**(86) **PCT No.: PCT/DE01/01886**



FULLY-AUTOMATIC, ROBOT-ASSISTED CAMERA GUIDANCE USING POSITIONS SENSORS FOR LAPAROSCOPIC INTERVENTIONS

[0001] The present invention is directed to an operating system for the implementation of operative interventions, as defined in the preamble of the attached claim 1, and to a method for the follow-up of a laparoscope attached to a robot arm for the visualization of operative interventions, as defined in the preamble of the attached claim 7.

[0002] Minimally invasive surgery is gaining more and more significance as an alternative to an open surgical intervention. These interventions are a matter of operating methods wherein operations are implemented with the smallest possible operation wounds.

[0003] In specific fields of this minimally invasive surgery, for example in laparoscopic interventions wherein instruments are introduced into the abdominal region of the patient through small entry openings and are guided and operatively utilized therein by a surgeon, the necessity derives that the instruments be visualized on an external picture screen with a camera (laparoscope) additionally introduced into the abdominal region. For example, the operating technique is currently routinely utilized in the resection of the gallbladder. The surgeon thereby monitors the movement of the instruments only via the picture screen.

[0004] In the Prior Art, the camera is guided during the intervention by an operating (OP) assistant, who assists the surgeon. In addition to the need for additional personnel and the costs that are thereby incurred, however, the following problems arise due to the manual camera guidance:

[0005] The surgeon and the assistant guiding the camera must collaborate in the closest possible proximity and with the utmost degree of consultation during the operation. The assistant must often work predictively since he/she must not only acquire the current position of instruments but must also support the planned instrument guidance of the surgeon.

[0006] The camera guidance becomes imprecise and restless given flagging attention and fatigue on the part of the assistant, particularly given operating procedures that last a long time. Further, the instructions that the surgeon gives the camera-guiding OP assistant must be very precise. These instructions can sometimes be misinterpreted.

[0007] Moreover, camera guidance generally does not require any highly qualified training, so that operating assistants do not approach this task all too gladly.

[0008] On approach for minimizing the described problems is comprised in fixing the camera with instrument mounts. However, the follow-up of the camera by an OP assistant during the operation is thereby not eliminated.

[0009] The use of a robot with whose assistance the laparoscope is interactively controlled and moved by the surgeon is also known. Given this method, however, the surgeon must additionally concentrate on the control of the camera.

[0010] Another approach is disclosed by U.S. Pat. No. 5,820,545, "Method of Tracking a Surgical Instrument with a Mono or Stereo Laparoscope". The surgical instruments introduced into the body are thereby provided with color-coded markings. These markings are detected by the camera

introduced into the body, whereby the camera (laparoscope) is positioned such with the assistance of a robot that the surgical instruments guided in the operation are also in the field of view of the camera. When, however, the distance of the surgical instruments from the introduced camera is also to be regulated by the robot, then the use of a stereo camera or, respectively, of a stereo laparoscope is necessary, i.e. of a camera having two optical devices.

[0011] This method, however, has the disadvantage that the instruments must always be in the field of view of the camera for the follow-up of the camera since, otherwise, the camera loses the position of the instruments. Moreover, the follow-up of the camera can be deteriorated due to contamination of the color markings (for example, with blood).

[0012] WO 97/29709 A1, "Medical Procedures and Apparatus Using Intrabody Probes", discloses a method and an apparatus wherein an instrument probe is guided through the body of a patient. The position of this instrument probe relative to another probe situated in the body of the patient is thereby determined, and the instrument probe is guided through the body based on the identified position relative to one another.

[0013] Cinquin, P. et al., "Computer Asisted [sic] Medical Interventions [sic]", IEEE Engineering in Medicine and Biology, May/June 1995, pages 254 through 263, describes computer-assisted operative interventions upon employment of position and shape sensors.

[0014] It is thus the object of the present invention to offer an operation system for the implementation of operative interventions according to the preamble of the attached claim 1 and a method applied in this operation system for the implementation of operative interventions according to the preamble of the attached claim 7 wherein an exact, automatic positioning of the laparoscope with a robot is enabled.

[0015] This object is achieved by an operation system for the implementation of operative interventions according to the attached claim 1 and by a method applied in this operation system for the follow-up of a laparoscope attached to a robot arm according to the attached claim 7.

[0016] According to the present invention, the laparoscope introduced into the body is fully automatically controlled or, respectively, re-adjusted by a robot that receives its commands from a control computer. The follow-up of the laparoscope ensues on the basis of the identified positions of the surgical instrument, so that the surgical instrument is always located in the field of view of the laparoscope.

[0017] First, the inventive, automatic camera guidance eliminates the manual camera guidance by an assistant that is fraught with the described disadvantages. Second, the surgeon can concentrate fully on his/her actual task, i.e. the guidance of the surgical instruments.

[0018] The employed navigation system having sensors attached to the laparoscope and to the surgical instrument can be a matter of commercially available optical systems (for example, Polaris system of the Northern Digital company), electromagnetic systems (for example, electromagnetic Bird system of the Ascension company) or of systems based on acoustic waves.

[0019] Given employment of optical systems, care must be exercised to see that the position sensors are extra-

corporeally attached, i.e. that the position sensors must be situated outside the body during the operative intervention, in order to enable a optical connection to a transmitter or, respectively, to one another.

[0020] Given the electromagnetic and sound-based systems, the position sensors can be attached either extra-corporeally as well as to the tip or, respectively, in the proximity of the tip of the laparoscope or, respectively, of the surgical instrument.

[0021] Given the extra-corporeal fastening, only rigid instruments can be employed wherein the received coordinates of the extra-corporeally attached sensors are converted onto the instrument tip by means of a calibration.

[0022] Given fastening of the position sensors to the tip or, respectively, in the proximity of the tip of the laparoscope or, respectively, surgical instrument, the position sensors are co-introduced into the body in the intervention. This has the advantage that flexible instruments can also be utilized. However, these instruments with position sensors also occupy more space in the body.

[0023] The present invention is preferably employed in minimally invasive, laparoscopic interventions.

[0024] For example, a robot of Computer-Motion, Goleta, Calif., USA, can be utilized for the robot that guides the camera.

[0025] The present invention is explained in greater detail below on the basis of a preferred exemplary embodiment with reference to the attached FIGURE, whose sole FIG. 1 schematically shows an inventive operation system.

[0026] As shown in FIG. 1, the camera or, respectively, the laparoscope 5 is introduced into the body of the patient, for example in the region of the epigastrium in FIG. 1, and is moved with a robot arm 10 with the assistance of the robot 4—the laparoscope 5 is thereby fixed to the robot arm 10 via an instrument mount 8.

[0027] The laparoscope 5 as well as one or more surgical instruments 6 are provided with position sensors 7 that generate orientation information with whose assistance the positions of the laparoscope 5 and of the surgical instrument 6 can be calculated in the navigation system 3 and forwarded to a control computer 1. The position acquisition and calculation can thereby ensue continuously or in intervals.

[0028] The example of FIG. 1 proceeds on the basis of an electromagnetic navigation system wherein an electromagnetic field 9 is emitted by an emitter 2 that is connected via an interface 12 to the navigation system 3 or, respectively, a central unit of the navigation system. This electromagnetic field is detected by the position sensors 7, which generate the orientation information on the basis of the electromagnetic field 9. The spatial positions and dihedral angles of the laparoscope and of the surgical instrument or instruments 6 or, respectively, their spatial positions relative to one another can be very precisely detected with the assistance of the position sensors 7. These spatial positions and angle information are acquired by the control computer 1, which subsequently drives the robot 4 such and, thus, aligns the laparoscope 5 such that all surgical instruments 6 to be monitored are in the field of view of the camera, whose images are output on a picture screen, and are thus in the field of view of the surgeon.

[0029] The present invention is suitable for employment both with a mono-laparoscope (having one optics) as well as with a stereo-laparoscope (having two optics).

[0030] The control computer 1 sends the commands for the follow-up of the laparoscope 5 to the robot 4 via an interface 13. On the basis of the commands received from the control computer 1, the robot 4 re-adjusts the laparoscope 5 secured to the robot arm 10 in conformity with the movements of the surgical instrument 6 guided by the surgeon.

[0031] With the assistance of the articulated arm 10, the movement of the laparoscope 5 can ensue in six degrees of freedom: right-left, up-down, near-far, incline, tilt, turn. It is thereby possible to exclude a specific plurality of degrees of freedom. This is especially important when a movement of the laparoscope 5 in specific directions or by specific dihedral angles would jeopardize the operation safety or when the surgical instrument 6 is only guided in a specific region of the operating field.

[0032] The control computer 5 acquires the spatial positions and dihedral angles of the laparoscope 5 (camera) and of the surgical instruments 6 either continuously or at intervals on the basis of the position sensors 7 attached thereat. When the control computer 1 recognizes that laparoscope 5 and surgical instrument 6 are in positions wherein the surgical instrument 6 cannot be acquired by the camera, the control computer 1 gives the command to the robot 4 via an interface 13 (for example, serial or parallel) to move such that the surgical instrument 6 is located in the middle or in a defined region of the camera's field of view. The distance between the laparoscope 5 and the surgical instrument 6 can likewise be regulated such in this way that the distance does not downwardly or upwardly transgress a prescribable tolerance interval. The acquisition of the spatial coordinates of the laparoscope 5 and of the surgical instrument 6 and the corresponding drive of the robot arm 10 is thus executed in a servoloop.

1. Operation system for the implementation of operative interventions, comprising

a laparoscope (5) attached to a robot arm (10) for visualizing the interventions,

a surgical instrument (6) for the implementation of the interventions,

characterized by a respective position sensor (7) at laparoscope (5) and surgical instrument (6) for generating orientation information, and

by a navigation system (3) for determining the positions of laparoscope (5) and surgical instrument (6) on the basis of the orientation information generated by the position sensors (7), whereby the laparoscope (5) is automatically re-adjusted such by the robot arm (10) with the assistance of the identified positions that the surgical instrument (6) is located in the field of view of the laparoscope (5).

2. Operation system according to claim 1, characterized in that the navigation system (3) is based on acoustic waves.

3. Operation system according to claim 1, characterized in that the navigation system (3) is based on electromagnetic waves.

4. Operation system according to claim 1, characterized in that the navigation system (3) is based on optical waves.

5. Operation system according to one of the claims 1 through 4, characterized in that the position sensors (7) are attached to the tip of the laparoscope (5) or, respectively, of the surgical instrument (6).

7. Operation system according to one of the claims 1 through 5, characterized in that the position sensors (7) are extra-corporeally applied to the laparoscope (5) or, respectively, to the surgical instrument (6).

7. Method for the follow-up of a laparoscope (5) attached to a robot arm (10) for visualizing operative interventions, having

a surgical instrument (6) for the implementation of the interventions, comprising the steps:

generating orientation information of laparoscope (5) and surgical instrument;

determining the positions of laparoscope (5) and surgical instrument (6) and the basis of the generated orientation information; and

automatic follow-up of the laparoscope (5) with the assistance of the identified positions such that the surgical instrument (6) is located in the field of view of the laparoscope (5).

8. Method according to claim 7, characterized in that it is utilized in minimally invasive surgical interventions.

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专利名称(译)	全自动，机器人辅助摄像头引导装置，用于腹腔镜介入治疗的位置传感器		
公开(公告)号	US20040015053A1	公开(公告)日	2004-01-22
申请号	US10/276355	申请日	2001-05-17
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发明人	BIEGER, JOHANNES GRAUMANN, RAINER RAHN, NORBERT		
IPC分类号	A61B1/313 A61B5/06 A61B34/00 A61B34/20 A61B90/00 A61B1/00		
CPC分类号	A61B1/00149 A61B1/313 A61B5/06 A61B5/064 A61B2019/5251 A61B19/52 A61B19/5212 A61B19/5244 A61B19/22 A61B34/20 A61B34/70 A61B90/36 A61B90/361 A61B2034/2051		
优先权	10025085 2000-05-22 DE		
其他公开文献	US6926709		
外部链接	Espacenet USPTO		

摘要(译)

在用于进行外科手术的方法和操作系统中，相应的位置传感器安装在腹腔镜和用于进行介入的手术器械上，并且导航系统被提供有来自这些位置传感器的定向信息。基于该定向信息，导航系统自动控制安装有腹腔镜的机器人臂，以始终将手术器械保持在腹腔镜的视野中。

