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(71) Applicant *(for all designated States except US)*: **CALABRIAN HIGH TECH SRL** [IT/IT]; Ponte Bucci Cubo 45C, I-87036 Rende (IT).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **DANIELI, Guido, A.** [IT/IT]; Dipartimento di Meccanica, Università della Calabria, I-87036 Rende (IT). **RICCIPETITONI, Giovanna** [IT/IT]; Ospedale dell'Annunziata, I-87036 Cosenza (IT).

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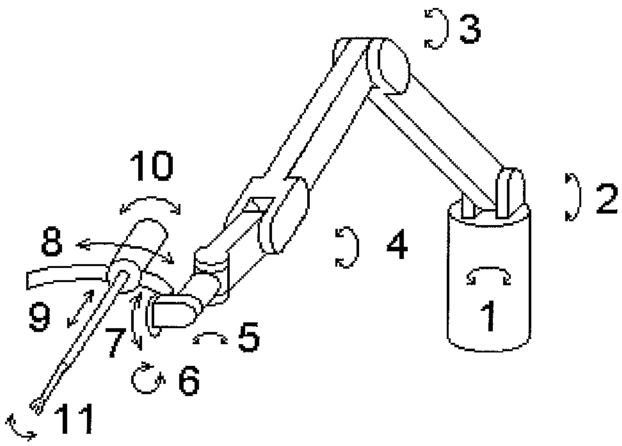
(54) Title: ROBOTIZED SYSTEM FOR THE CONTROL AND MICROMETRIC ACTUATION OF AN ENDOSCOPE



(57) Abstract: The invention is relative to a new robotized system to control and actuate with micrometric precision an endoscope, particularly, but not exclusively for neonatal laparoscopy. The basic structure is made by three to five self balancing arms (which can be moved passively) able on command, to block itself in the actual position, passing in mode active Robot. At least two of the arms sustain the actuation system of the surgical endoscope, each being able to rotate the instrument sheet along two axes mutually perpendicular and to the sheet itself holding fixed the insertion point of the instrument into the patient, being also able to rotate the instrument with respect to the sheet and to control the axial advancement, the instrument's actuation (scissor, forceps or anything else) being controlled in position with micrometric precision. Presence of an haptic interface is also foreseen, to inform the doctor on the resistance opposed to the various actions. The remaining arms are used to hold the other accessories (video camera, insufflator, etc) eventually moving them, on doctor request, that commands and controls everything from a console. The purpose of the present equipment is to allow controlling the movement with a precision not obtainable with free hand, while utilizing the entire manual instrumentation presently available in the hospitals.

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ROBOTIZED SYSTEM FOR THE CONTROL AND MICROMETRIC ACTUATION OF AN ENDOSCOPE

General Description of the field of application of the invention.

Least Invasive Surgery is taking more and more momentum as a perfect method to reduce invasiveness, recovery times and consequently also global costs of surgical procedures, minimizing also related risks. In fact the reduction of the surgeries invasiveness is coupled with their much higher tolerability by the organism, that produces a faster recovery, allowing sometimes even patient's dismissal from the hospital on the same day of the surgery. Instruments used for such surgeries are rigid endoscopes, most commonly used the laparoscope. This is usually operated by hand by the doctor, that controls its movements, included the actuation of the operating instrument (forceps, scissors, etc.). Two or more further instruments are present, to inflate the abdomen using CO2, and a video camera. Since the instrument control may not be easy, especially if the movements required are very fine, Robots have been introduced, allowing a finer motion control, that is in any event always actuated by the doctor. These allow also to employ only one medical operator, rather than to use, as it occurs now, two or three operators. Substantially the system allows a kind of motion demultiplication, improving its control. However in these Robots the endoscopic instrument is integrated not only with the Robot itself, but even with the auxiliary instruments, increasing the surgery costs, determined, not only by the Robot, but also by the cost of the specific disposable instruments. Furthermore the endoscopes used are of non miniaturized dimensions (>8 -10 mm.).

The idea of the present invention is to develop an instrument allowing the same type of actuation with extra fine motion control, using however the la endoscopic instruments existing, which not only should allow a good saving for the hospitals, reutilizing existing instruments, but also to utilize small size instruments (2 – 3 mm in diameter), necessary in neonatal and paediatric surgery, currently not usable in other way than free hand, while precise position control could be more useful, such in the case of neonatal laparoscopy, where body structures are, sort to say, miniaturized.

Moreover, since during surgeries the doctor is used to feel the effort to accomplish the different operations, an haptic interface will have to be supplied, allowing to feel the physical perception of the force exerted.

Description of the preferred embodiment.

Basically, each arm (either operator or auxiliary) may be similar to those described in Italian patent application N° CS2002A000005, of 28/05/2002, N° CS2002A000022., of 7/11/2002 and N° CS2005A000010., of 28/06/2005 which are explicitly referred to. Thus the preferred embodiment of each arm is made according one of the two alternatives presented in the last patent application quoted. The first presents a first hinge having vertical axis, from which departs a second arm, bearing at the end a second hinge having horizontal axis, perpendicular to the arm. From such second hinge a third arm departs, at the end of which a third hinge having horizontal axis and parallel to that of the second hinge is present. The fourth arm is similar to the third, bearing at the end again a fouth hinge, also parallel to the last two. From the fourth hinge departs a very short fifth arm bearing at the end a fifth hinge, whose axis should lie on a plane parallel or passing through the first hinge, followed by a sixth arm, also very short, which presents at the other estreme another hinge, whose axis is perpendicular to that of the fifth hinge, and, in extended configuration, also to that of the fourth (the axis of the sixth hinge is thus coaxial with the sixth arm). Each hinge presents both an encoder to measure the angle formed between the arms, and a motor allowing relative motion between the member on which is placed and a spring, preferably torsion, whose other extreme is è connected to the following arm. In parallel to the torsion spring is placed a brake allowing direct transmission of motion from the motor, bypassing the spring, transforming the system in a robot.

Alternatively it will be possible to use a SCARA type kinematic chain mounted on a vertical counterbalanced slider to which a third hinge having vertical axis is added, followed by two more hinges having axes mutually perpendicular positioned in such a way as to complete the wrist of the kinematic chain.

This way the doctor may freely bring the instrument, characterized by a self balancing active or passive system, in proximity of the work zone, connect the robotized equipment to the endoscopic instruments, already positioned, and require the transition in Robot mode, that will block the hinges and will be ready for the surgical phase. At the extremity of the surgical Robot a new system bearing at least five degrees of freedom will be placed, two of which allow to rotate the surgical instrument, about the point of insertion of the instrument into the patient's skin, along two mutually perpendicular axes, also perpendicular to the instrument. A third degree of freedom allows the instrument to rotate about its axis with respect to the sheet, while a fourth will control the axial displacement again with respect to the sheet. Finally the fifth degree of freedom will be dedicated to the actuation of the surgical instrument, forceps or scissor or whatever else.

The axial advancement and actuation systems will bear force sensors able to evaluate the resisting forces in the various manoeuvres in order to supply the surgeon an indication on possible problems. These indications could be both a variable force or an array of leds more or less enlighted in order to be clearly perceived. Naturally it is possible to use both systems for redundancy. And since usually the surgical instruments are two, all this will be present on two arms. The remaining arms will not bear this further five degrees of freedom control system, but will be controllable in any event by the surgeon through the console. He will hence have the possibility to modify the angle relative to the skin surface through a control system that will act in the same time on all different degrees of freedom in order to obtain the motion requested, being also in this case possible to include an haptic interface.

At the patient's side the console will be placed, on which all commands of the surgical and auxiliary robots will be hosted, so that the doctor will have full control of the entire surgical theatre, which is actually shared with other operators. The system will be completed by a series of adaptors allowing to connect each element of the traditional endoscope with the robotic system.

Figure 1 presents a surgical robotic arm, holding as end effector the five degrees of freedom system, that allows actuating the surgical endoscope as previously explained. It is clear that, should the endoscope have more than three degrees of freedom with respect to the sheet, these will be added to the end effector.

The following Figure 2 presents a clearer representation of the five degrees of freedom end effector, where is schematically shown the method of control of the instrument rotation about the two axes perpendicular to the surgical instrument. As can be seen these rotations are obtained using a first hinge (1) whose axis passes through the insertion point of the instrument in the skin, and by a semi ring (2) whose radius is equal to the distance from the same point. If the semi ring opening were of 180°, then the rotation about hinge 1 would cause the pure rotation of the instrument about an axis perpendicular to the ring itself, while the translation about the semi-ring should cause the rotation in direction perpendicular to the first. If instead the angle were less than 180° the two modes would be combined, which could be easily corrected via software. In the same figure with (3) is indicated the gear that, acting on a rack, allows axial motion, while gear (4) produces the axial rotation of the entire block, and gear (5) activates the surgical instrument. However, using a second semi - ring, or even better a sector of ring, it is possible to generate a hinge having its axis in the right position, even in absence of physical constraints in the axis region. This is shown in the side view of the same Figure.

Figure 3 shows a possible kit of robotized actuation of an existing endoscope. Note that the lower gear, fixed to the instrument shaft, allows its rotation of 360 degrees about its axis. Meanwhile, the upper gear, when rotated by an angle different from that of the lower gear, activates the instrument's action (opening or closing). Obviously the motion control system will operate in such a way that the surgeon will have separated command systems for the two actions, while the software will give the correct commands to the different motors. Note also that the entire group including semi ring up to the instrument must all be sterile, being commanded by four motors placed on the last link of the robotic arm, via animated cables able to transmit rotations and torque (such as a Teflon tube holding inside it a steel spring), also sterile, while between motors and animated cables the transducers used for the haptic response could be positioned.

Claims:

1) Robotized system to control the position and actuate a conventional endoscopic instrument composed by a certain number of robotized arms, by an end effector bearing at least five degrees of freedom fully sterilizable, by a system of connection of the existing instruments to the five degrees end effector, also sterilizable, by a system of control in real time of the motion of the surgical instrument and of the auxiliary arms operated by a single surgeon, and by a system of detection of the acting forces and relative haptic representation.

2) In particular the system of claim 1 could present self balancing arms movable in a passive way but lockable upon request to transform themselves in robot mode.

3) In particular the end effector bearing at least five degrees of freedom fully sterilizable of claim 1 could allow rotation of the surgical instrument in two perpendicular directions, also perpendicular to the instrument's shaft, having centre in the patient's entrance hole, the 360° rotation about its axis, the axial translation with respect to the sheet, and the instrument's actuation.

4) In particular the system of connection of the existing instruments to the five degrees end effector of claim 1 must allow 360° of rotation about instrument's axis.

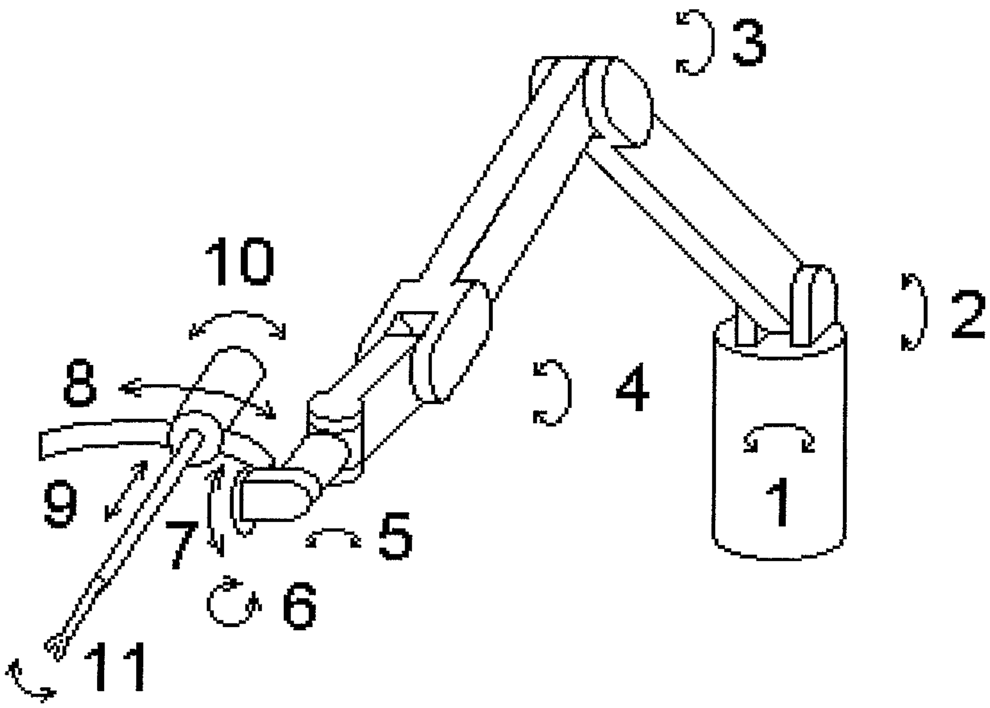

Figure 1

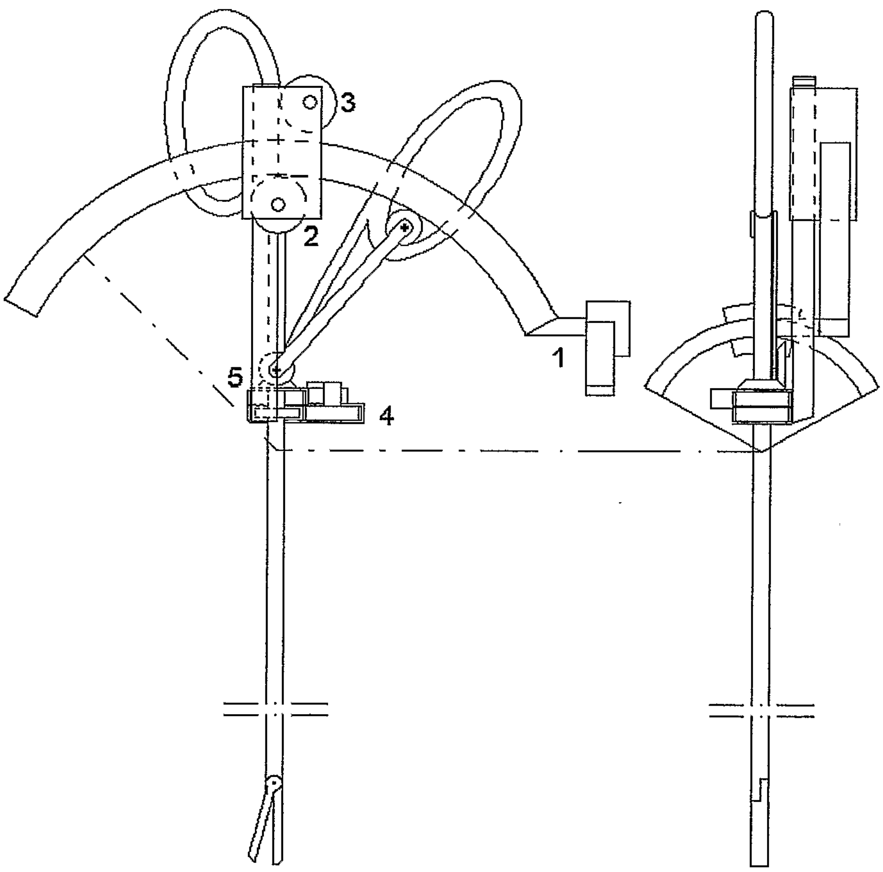

Figure 2

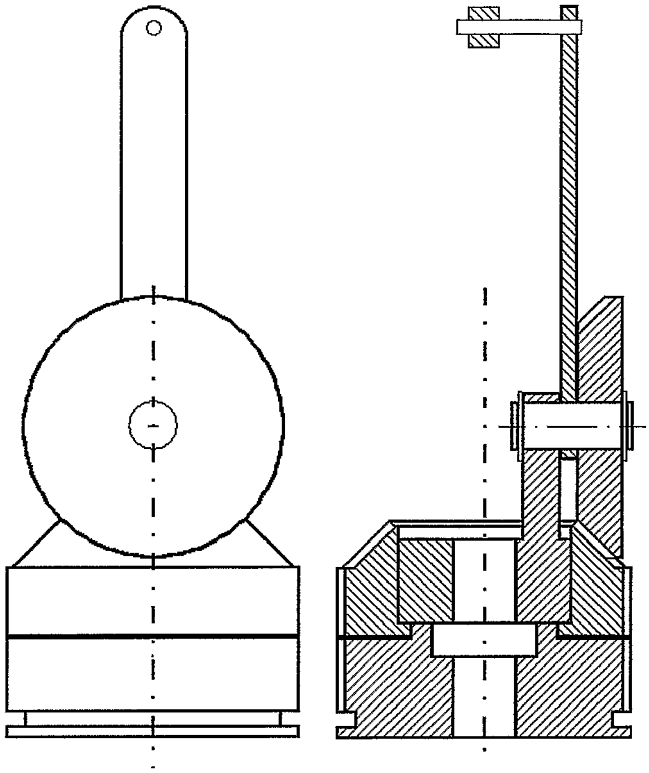

Figure 3

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
A61B19/00

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)
A61B

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 practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 572 999 A (FUNDA ET AL) 12 November 1996 (1996-11-12) figures 1-4 column 4, line 19 - column 5, line 18 column 16, line 57 - line 67	1-4
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Y	WO 03/099152 A (CALABRIAN HIGH TECH S.R.L.) 4 December 2003 (2003-12-04) abstract; figures 1,2 page 2, line 29 - line 33	2

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
25 November 2005	12/12/2005

Name and mailing address of the ISA	Authorized officer
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IT2005/000486

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

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patsnap

专利名称(译)	用于内窥镜的控制和微观致动的机器人系统		
公开(公告)号	[EP1843713A1]	公开(公告)日	2007-10-17
申请号	EP2005778903	申请日	2005-08-08
[标]申请(专利权)人(译)	卡拉布里亚HIGH TECH		
申请(专利权)人(译)	HIGH TECH卡拉布里亚S.R.L.		
当前申请(专利权)人(译)	HIGH TECH卡拉布里亚S.R.L.		
[标]发明人	DANIELI GUIDO A DIPARTIMENTO DI MECCANICA RICCIPETITONI GIOVANNA		
发明人	DANIELI, GUIDO, A., DIPARTIMENTO DI MECCANICA RICCIPETITONI, GIOVANNA		
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优先权	102004901236858 2004-08-09 IT 102005901323914 2005-06-28 IT		
外部链接	[Espacenet]		

摘要(译)

本发明涉及一种新的自动化系统，用于以微米精度控制和致动内窥镜，特别是但不限于新生儿腹腔镜检查。基本结构由三到五个自动平衡臂（可被动地移动）按指令制成，在实际位置阻挡自身，通过模式主动机器人。至少两个臂支撑外科手术内窥镜的致动系统，每个臂能够沿两个相互垂直的轴旋转仪器片并且使片本身保持将器械的插入点固定到患者体内，也能够旋转仪器相对于板材并控制轴向推进，仪器的驱动（剪刀，镊子或其他任何东西）以微米精度控制在适当位置。还预见到存在触觉界面，以告知医生与各种动作相反的阻力。其余的手臂用于固定其他配件（摄像机，吹气器等），最终根据医生的要求移动它们，从控制台命令和控制一切。本设备的目的是允许用自由手无法获得的精度控制运动，同时利用医院目前可用的整个手动仪器。