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Jensen et al.

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(54) **SYSTEM AND METHOD FOR RELEASABLY HOLDING A SURGICAL INSTRUMENT**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/521,253**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **A61B 17/28**
(52) **U.S. Cl.** **606/205**
(58) **Field of Search** 606/205, 206, 606/207, 208, 130, 186, 209, 210

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,418,184	A	5/1922	Trunick
2,815,697	A	12/1957	Saunders-Singer
2,901,258	A	5/1959	Brandafi
3,145,333	A	8/1964	Pardini et al.
3,463,329	A	8/1969	Gartner
3,818,125	A	6/1974	Butterfield
3,921,445	A	11/1975	Hill et al.

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

CH	482439	1/1970
DE	2819976	11/1979
DE	3806190	9/1988
DE	9204118	3/1992
DE	4213426	10/1992
EP	291292	11/1988

(List continued on next page.)

OTHER PUBLICATIONS

US 5,100,411, 3/1992, Koutrouvelis (withdrawn)
Abstracts and Video Catalogue, 3rd World Congress of Endoscopic Surgery Abstracts, *Surgical Laporoscopy & Endoscopy*, vol. 3, No. 3, (1993) pp. 248–275.

(List continued on next page.)

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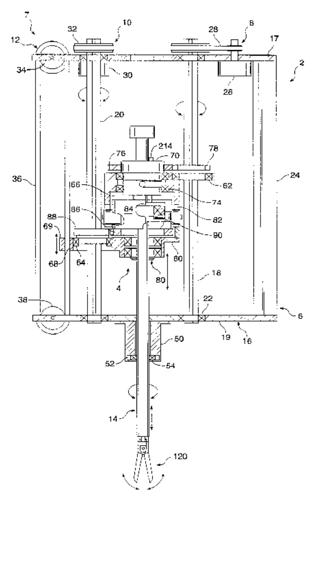
(57) **ABSTRACT**

The invention is directed to a system and method for releasably holding a surgical instrument **(14)**, such as an endoscopic instrument configured for delivery through a small percutaneous penetration in a patient. The instrument comprises an elongate shaft **(100)** with a pair of mounting pins **(116)** laterally extending from the shaft between its proximal and distal ends. An instrument holder comprises a support having a central bore **(202)** and an axially extending slot **(204)** for receiving the instrument shaft and the mounting pins. A pair of locking slots **(206)** are cut into the support transversely to and in communication with the axial slot so that the mounting pins can be rotated within the locking slots. The instrument support further includes a latch assembly for automatically locking the mounting pins within the locking slots to releasably couple the instrument to the instrument holder. With this twist-lock motion, the surgeon can rapidly engage and disengage various instruments from the holder during a surgical procedure, such as open surgery, laparoscopy or thoracoscopy.

13 Claims, 9 Drawing Sheets



U.S. PATENT DOCUMENTS

3,923,166	A	12/1975	Fletcher et al.
3,934,201	A	1/1976	Majefski
4,058,001	A	11/1977	Waxman
4,113,115	A	9/1978	Yoshio
4,150,326	A	4/1979	Engleberger et al.
4,221,997	A	9/1980	Flemming
4,260,319	A	4/1981	Motoda et al.
4,264,266	A	4/1981	Trechsel
4,349,837	A	9/1982	Hinds
4,367,998	A	1/1983	Causer
4,419,041	A	12/1983	Rose
4,436,684	A	3/1984	White
4,456,961	A	6/1984	Price et al.
4,474,174	A	10/1984	Petruzzi
4,490,022	A	12/1984	Reynolds
4,503,854	A	3/1985	Jako
4,506,393	A	3/1985	Murphy
4,510,574	A	4/1985	Guittet et al.
4,517,963	A	5/1985	Michel
4,562,463	A	12/1985	Lipton
4,582,067	A	4/1986	Silverstein et al.
4,583,117	A	4/1986	Lipton et al.
4,601,000	A	7/1986	Montabert
4,636,138	A	1/1987	Gorman
4,638,799	A	1/1987	Moore
4,651,201	A	3/1987	Schoolman
4,672,963	A	6/1987	Barken
4,722,056	A	1/1988	Roberts et al.
4,728,974	A	3/1988	Nio et al.
4,744,363	A	5/1988	Hasson
4,750,475	A	6/1988	Yoshihashi
4,750,487	A	6/1988	Zanetti
4,751,925	A	6/1988	Tontarra
4,762,455	A	8/1988	Coughlan et al.
4,764,944	A	8/1988	Finlayson
4,788,482	A	11/1988	Tachibana et al.
4,791,588	A	12/1988	Onda et al.
4,791,934	A	12/1988	Brunnett
4,808,898	A	2/1989	Pearson
4,815,006	A	3/1989	Rhodes et al.
4,826,392	A	5/1989	Hayati
4,833,383	A	5/1989	Skarr et al.
4,837,703	A	6/1989	Kakazu et al.
4,837,734	A	6/1989	Ichikawa et al.
4,853,874	A	8/1989	Iwamoto et al.
4,854,301	A	8/1989	Nakajima
4,855,822	A	8/1989	Narendra et al.
4,860,215	A	8/1989	Seraji
4,862,873	A	9/1989	Yajima et al.
4,863,133	A	9/1989	Bonnell
4,873,572	A	10/1989	Miyazaki et al.
4,899,730	A	2/1990	Stennert et al.
4,921,393	A	5/1990	Andeen et al.
4,922,338	A	5/1990	Arpino
4,930,494	A	6/1990	Takehana et al.
4,941,106	A	7/1990	Krieger
4,942,539	A	7/1990	McGee et al.
4,943,296	A	7/1990	Funakubo et al.
4,947,702	A	8/1990	Kato
4,979,949	A	12/1990	Matsen, III et al.
4,989,253	A	1/1991	Liang et al.
4,996,975	A	3/1991	Nakamura
5,002,418	A	3/1991	McCown et al.
5,020,001	A	5/1991	Yamamoto et al.
5,020,933	A	6/1991	Salvestro et al.
5,036,463	A	7/1991	Abela et al.
5,045,936	A	9/1991	Lobb et al.
5,046,022	A	9/1991	Conway et al.
5,050,608	A	9/1991	Watanabe et al.
5,056,031	A	10/1991	Nakano et al.
5,060,532	A	10/1991	Barker
5,062,761	A	11/1991	Glachet
5,077,506	A	12/1991	Krause
5,078,140	A	1/1992	Kwoh
5,078,142	A	1/1992	Siczek et al.
5,086,401	A	2/1992	Glassman et al.
5,090,401	A	2/1992	Schwicker
5,096,236	A	3/1992	Thöny
5,097,839	A	3/1992	Allen
5,098,426	A	3/1992	Sklar et al.
5,125,888	A	6/1992	Howard et al.
5,141,519	A	8/1992	Smith et al.
5,142,930	A	9/1992	Allen et al.
5,154,717	A	10/1992	Matsen, III et al.
5,170,347	A	12/1992	Tuy et al.
5,182,641	A	1/1993	Dienr et al.
5,184,601	A	2/1993	Putman
5,187,574	A	2/1993	Kosemura et al.
5,188,111	A	2/1993	Yates et al.
5,201,325	A	4/1993	McEwen et al.
5,201,743	A	4/1993	Haber et al.
5,209,747	A	5/1993	Knoepfler
5,216,596	A	6/1993	Weinstein
5,217,003	A	6/1993	Wilk
5,219,351	A	6/1993	Teubner et al.
5,221,283	A	6/1993	Chang
5,222,499	A	6/1993	Allen et al.
5,228,429	A	7/1993	Hatano
5,230,338	A	7/1993	Allen et al.
5,235,510	A	8/1993	Yamada et al.
5,236,432	A	8/1993	Matsen, III et al.
5,240,011	A	8/1993	Assa
5,251,127	A	10/1993	Raab
5,253,706	A	10/1993	Reid
5,257,203	A	10/1993	Riley et al.
5,257,998	A	11/1993	Ota et al.
5,260,319	A	11/1993	Effland et al.
5,261,404	A	11/1993	Mick et al.
5,264,266	A	11/1993	Yokoyama et al.
5,271,384	A	12/1993	McEwen et al.
5,273,039	A	12/1993	Fujiwara et al.
5,279,309	A	1/1994	Taylor et al.
5,280,427	A	1/1994	Magnusson et al.
5,281,220	A	1/1994	Blake, III
5,284,130	A	2/1994	Ratliff
5,289,273	A	2/1994	Lang
5,299,288	A	3/1994	Glassman et al.
5,313,306	A	5/1994	Kuban et al.
5,325,866	A	7/1994	Krzyzanowski
5,339,799	A	8/1994	Kami et al.
5,343,391	A	8/1994	Mushabac
5,368,015	A	11/1994	Wilk
5,368,428	A	11/1994	Hussey et al.
5,371,536	A	12/1994	Yamaguchi
5,377,310	A	12/1994	Jain et al.
5,377,683	A	1/1995	Barken
5,382,885	A	1/1995	Salcudean et al.
5,397,323	A	3/1995	Taylor et al.
5,398,685	A	3/1995	Wilk et al.
5,417,210	A	5/1995	Funda et al.
5,425,528	A	6/1995	Rains et al.
5,441,505	A	8/1995	Nakamura
5,445,166	A	8/1995	Taylor
5,474,566	A	12/1995	Alesi et al.
5,480,409	A	1/1996	Riza
5,515,478	A	5/1996	Wang
5,524,180	A	6/1996	Wang et al.
5,553,198	A	9/1996	Wang et al.
5,571,110	A	11/1996	Matsen, III et al.
5,572,999	A	11/1996	Funda et al.
5,630,431	A	5/1997	Taylor

5,631,973 A		5/1997	Green	
5,636,138 A		6/1997	Gilbert et al.	
5,649,956 A		7/1997	Jensen et al.	
5,657,429 A		8/1997	Wang et al.	
5,762,458 A		6/1998	Wang et al.	
5,815,640 A		9/1998	Wang et al.	
5,841,950 A		11/1998	Wang et al.	
5,855,583 A		1/1999	Wang et al.	
5,878,193 A		3/1999	Wang et al.	
5,907,664 A		5/1999	Wang et al.	
5,954,746 A	*	9/1999	Holthaus et al.	606/205
6,042,599 A	*	3/2000	Huttner et al.	606/208

FOREIGN PATENT DOCUMENTS

EP	595291	10/1993
EP	239409	5/1994
FR	2460762	6/1981
FR	2593106	7/1987
GB	2040134	8/1980
GB	2117732	3/1983
GB	494943	8/1995
WO	WO 91/04711	4/1991
WO	WO 92/16141	10/1992
WO	WO 93/13916	7/1993

OTHER PUBLICATIONS

Alexander, III, "Impacts of telemation on modern society" *1st CISM–IFTO MM Symposium*, vol. 2, pp. 122–130.

Asada et al., "Development of a Direct–Drive Arm Using High torque Brushless Motors," Chapter 7, pp. 583–599.

Askew et al., "Ground Control Tested for Space Station Freedom Robot Manipulators", Proceedings of the IEEE Virtual Reality Annual International Symposium, Seattle, Washington, USA, (Sep. 18–22, 1993) *Institute of Electrical and Electronics Engineers*, pp. 69–75.

Bejczy et al., "Controlling remote manipulators through kenesthetic coupling" *Computers in Mechanical Engineering* (Jul. 1983) pp. 48–60.

Bergamasco et al., "Advances interfaces for teleoperated biomedical robots" *IEEE Engineering in Medicine and Biology Society* 11^{th} Annual International Conference, (1989) pp. 912–913.

Besant et al., "Camera control for laparoscopic surgery by speech–recognizing robot: Constant attention and better use of personnel" *3^{rd} World Congress of Endoscopic surgery*, vol. 3, No. 3, (1993) pp. 271.

Blue Cross Magazine *Perspective* (First Quarter 1972) vol. 7, No. 1, p. 27.

Bowersox et al., "Vascular Applications of Telepresence Surgery: Initial Feasibility Studies in Swine" *J. Vasc. Surg.* 23:2 (Feb. 1996), pp. 281–287.

Charles et al., "Design of a surgeon–machine interface for teleoperated microsurgery" *IEEE Engineering in Medicine and Biology Society 11^{th} Annual International Conference*, (1989) pp. 0338–0884.

Colgate, "Power and Impedance scaling in bilateral manipulation" *Proceedings of 1991 IEEE International Conference on Robotics and Automation* (*Apr. 1991*) pp. 2292–2297.

Computer Motion, Inc. advertisement entitled "AESOP Automated Endoscopic System for Optimal Positioning"1 page total.

Corcoran, "Robots for the operating room,"*The New York Times,* (Jul. 1992) 4 pages total.

Das et al., "Kinematic control and visual display of redundant teleoperators," *IEEE* (1989) pp. 1072–1077.

Davies et al., "A surgeon robot for prostatectomies" *IEEE* (1991) pp. 870–877.

Dolan et al., "A robot in an operating room: A bull in china shop?" *IEEE* (1987) pp. 289–291.

Finlay et al., "Results of a feasibility study into applications for advanced medical robots" *National Research Council Canada/Joint Coordinating Forum for the International Advanced Robots Programme* (1988) pp. 2.1–2.6.

Fisher et al., "Virtual interface environment" *Proceedings IEEE/AIAA 7th Digital Avionics Systems Conference*, Forth Worth, Texas (Oct. 1986) pp. 346–350.

Finlay et al., "Controlling the movement of a surgical laparoscope" *IEEE* (May/Jun. 1995) pp. 2.1.–2.6.

Flatau, "Compact servo master–slave manipulator with optimized communication links" *Proceedings of 17^{th} conference on remote systems technology* (Nov. 1969) pp. 154–164.

Funda et al., "Constrained Cartesian motion control for teleoperated surgical robots" *IEEE* (1996) vol. 12, No. 3, pp. 453–465.

Galloway, Jr., et al., "A New Device for Interactive, Image–guided Surgery", *Proceedings of SPIE Conference on Medical Imaging* (Feb. 24–26, 1991), pp. 9–18.

Gayed et al., "An advanced control micromanipulator for surgical appellations" *Systems Science* (1987 vol. 13, No. 1–2, pp. 123–134.

Glauser et al., "Conception of a robot dedicated to neurosurgical operations" *IEEE* (*1991*) pp. 898–907.

Green et al., "Telepresence: Advanced teleoperator technology for minimally invasive surgery" *3rd World Congress of Endoscopic Surgery* (Jun. 1992) p. 49, abstract 704.

Green et al., "Telepresence Surgery" *IEEE Engineering in Medicine and Biology* (May/Jun. 1995) pp. 324–329.

Guerrouad et al., "S.M.O.S.: Stereotaxical Microtelamanipulator for Ocular Surgery," *IEEE Engineering in Medicine & Biology Society*, 11^{th} Annual International Conference, 1989, Medical Applications of Robotics, Track 16: Biorobotics, pp. 879–880.

Guinot et al., "Analysis of a robot wrist device for mechanical decoupling of end–effector position and orientation" *Six CISM–IFToMM Symposium on Theory and Practice or Robots and Manipulators* (Sep. 1986) pp. 42–53.

Hayati, et al., "Remote surface Inspection System", *Robotics and Autonomous Systems,* (*1993*) *Elsevier Science Publs.* 11:1:45–59.

Held et al., "Spatial Displays and Spatial Instruments" *Proceedings of a Conference Sponsored by NASA Ames Research Center and the School of Optometry, University of California* (Aug. 1987) p. 28–1 to 28–16.

Hill et al., "Telepresence surgery demonstration system" *IEEE* (1994) pp. 2302–2307.

Holler et al., "An ATM–based local communication system for telesurgery" *Interactive Technology and the New Paradigm for Healthcare* (*1995*) pp. 137–146.

Hunter et al., "Manipulation and dynamic mechanical testing of microscopic objects using a tele–micro–robot system" (1989) pp. 1553–1558.

Hurteau et al., "Laparoscopic Surgery Assisted by a Robotic Cameraman: Concept and Experimental Results" *Proceedings of IEEE Int'l. Conference on Robotics and Automation*, San Diego, California, USA, (May 80–13, 1994) pp. 2286–2289.

Inoue et al., "Six–axis bilateral control of an articulated slave manipulator using a Cartesian master manipulator" *Advanced Robotics*, (1990) vol. 4, No. 2, pp. 139–150.

"Introduction to a New Project for the National Research and Development Program (Large Scale Project) in FY 1991—Macromachine Technology", *Ministry of International Trade and Industry*, Japan, (Apr. 1991)pp. 1–11.
Jau et al., "Anthropomorhic remote manipulator" *NASA Technology Briefs* (Apr. 1991) p. 92.
Kavoussi et al., "Telerobotic assisted laparoscopic surgery: Initial laboratory and clinical experience" *Urology*.(Jul. 1994) vol. 44, No. 1, pp. 15–19.
Kazerooni, "Design and Analysis of the Statically Balanced Direct–Drive Robot Manipulator," *Robotics & Computer–Integrated Manufacturing*, 1989,l vol. 6, No. 4, pp. 287–293.
Kazerooni, "Human/robot interaction via the transfer of power and information signals/Part I: Dynamics and control analysis" *IEEE* (1989) pp. 1632–1640.
Kazerooni, "Humana/robot interaction via the transfer of power and information signals/Part I: Dynamics and control analysis" *IEEE* (1989) pp. 1641–1647.
Kim et al., A helmet mounted display for telerobotics? (1988) 33 *IEEE Computer Society International Conference*, pp. 543–547.
Krishnan et al., "Design considerations of a new generation endoscope using robotics and computer vision technology" Abstract No. 276, Session CL25/2, 1 page total.
Lavallee, "A New System for computer Assisted Neurosurgery", *IEEE Engineering in Medicine & Biology Society 11th International Conference*, vol. 3 p. 926–927.
Mair, "Industrial robotics" Prentice Hall, Publishers New York, pp. 41–54, 203–209.
Majima et al., "On a micro–manipulator for medical application–stability consideration of its bilateral controller" *Mechatronics* (1991) vol. 1, No. 3, pp. 293–309.
Matsushima, "Servo micro manipulator tiny micro mark–1" *4th Symposium on Theory and Practice of Robots and Manipulators*, (Sep. 1982) pp. 193–201.
Ng et al., "Robotic Surgery," *IEEE Engineering in Medicine and Biology,* (Mar. 1993) pp. 120–125.
Preising, B. et al., "A Literature Review: Robots in Medicine" *IEEE Engineering in Medicine and Biology,* vol. 10, Issue 2, (1991) pp. 13–22.
Richter, "Telesurgery may bridge future gaps" *Times Tribune,* (Jan. 24, 1988) pp. A–1 and A–16.
Sabatini et al., "Force Feedback–Based Telemicromanipulation for Robot Surgery on Soft–Tissues" *IEEE Engineering in Medicine Biology Society, 11th Annual International Conference* (1989) vol. 3 pp. 890–891.
Sato et al., "The safety assessment of human–robot systems (Architectonic principles of hazard–control systems)," *JSME International Journal* (Mar. 1989) vol. 32, No. 1, pp. 67–74.
Spain et al., "Stereo advantage for a peg–in–hole task using a force feedback manipulator" *SPIE* vol. 1256 Stereoscopic Display and Applications (1990) pp. 244–254.
Statutory Declaration of Dr. Philip S. Green, European Patent Convention in the Matter of EP–B–653922, Mathys & Squire, 100 Gray's Inn Road, London WC1X 8AL, United Kingdom, Ref. IK/I–12053.
Tachi et al., "Tele–existence master slave system for remote manipulation" (1990) *Proceedings of the 29th Conference on Decision and Control,* vol. 1, pp. 85–90.
Taubes, "Surgery in Cyberspace,"60 *Discover* (Dec. 1994) pp. 85–92.
Taylor et al., "A telerobotic assistant for laparoscopic surgery," *Computer Science* (Feb. 1994) pp. 1–24.
Taylor et al., "Taming the bull: Safety in a precise surgical robot" *IEEE* (1991) pp. 865–873.
Taylor et al., "A Telerobotic Assistant for Laparoscopic Surgery," *Engineering in Medicine and Biology*, May–Jun. 1995, pp. 279–288.
Tejima et al., "A new microsurgical robot system for corneal transplantation" *Precision Machinery* (1988) vol. 2, pp. 1–9.
Tendick et al., "Analysis of the surgeon's grasp for telerobotic surgical manipulation" *IEEE Engineering in Medicine and Biology Society 11th Annual International Conference* (1989) pp. 0914–0915.
Thring, "Robots and telechirs: Manipulators with memory; remote manipulators'; machine limbs for the handicapped" *Ellis Horwood Series in Engineering Science,* Chapter 5: pp. 122–131, pp. 9–11, Chapter 5: pp. 122–131, Chapter 7: pp. 194–195, Chapter 8: pp. 236–278, Chapter 9: p. 279.
Trevelyan, "Skills for a shearing robot: Dexterity and sensing" *Robotics Research/Second International Symposium* (1985) pp. 272–282.
Trevelyan et al., "Motion Control for a Sheep Shearing Robot" *IEEE Robotics Research Conference, the 1st International Symposium*, Carroll, NH, USA, (Aug. 1983) Conference No. 15357, Publication by MIT Press, pp. 175–190.
Trivedi et al., "Developing telerobotics systems using virtual reality concepts" *IEEE* (Jul. 1993) pp. 352–359.
United States patent application Ser. No. 07/823,932 (our reference 17516–004800) 38 pages total.
Vibet, "Properties of master–slave robots," *Motor–Con* (Apr. 1987) pp. 309–316.
Videotape: "Telepresence: Advanced Technology for Enhanced Minimally Invasive Surgery." Phil Green (Apr. 1992).

* cited by examiner

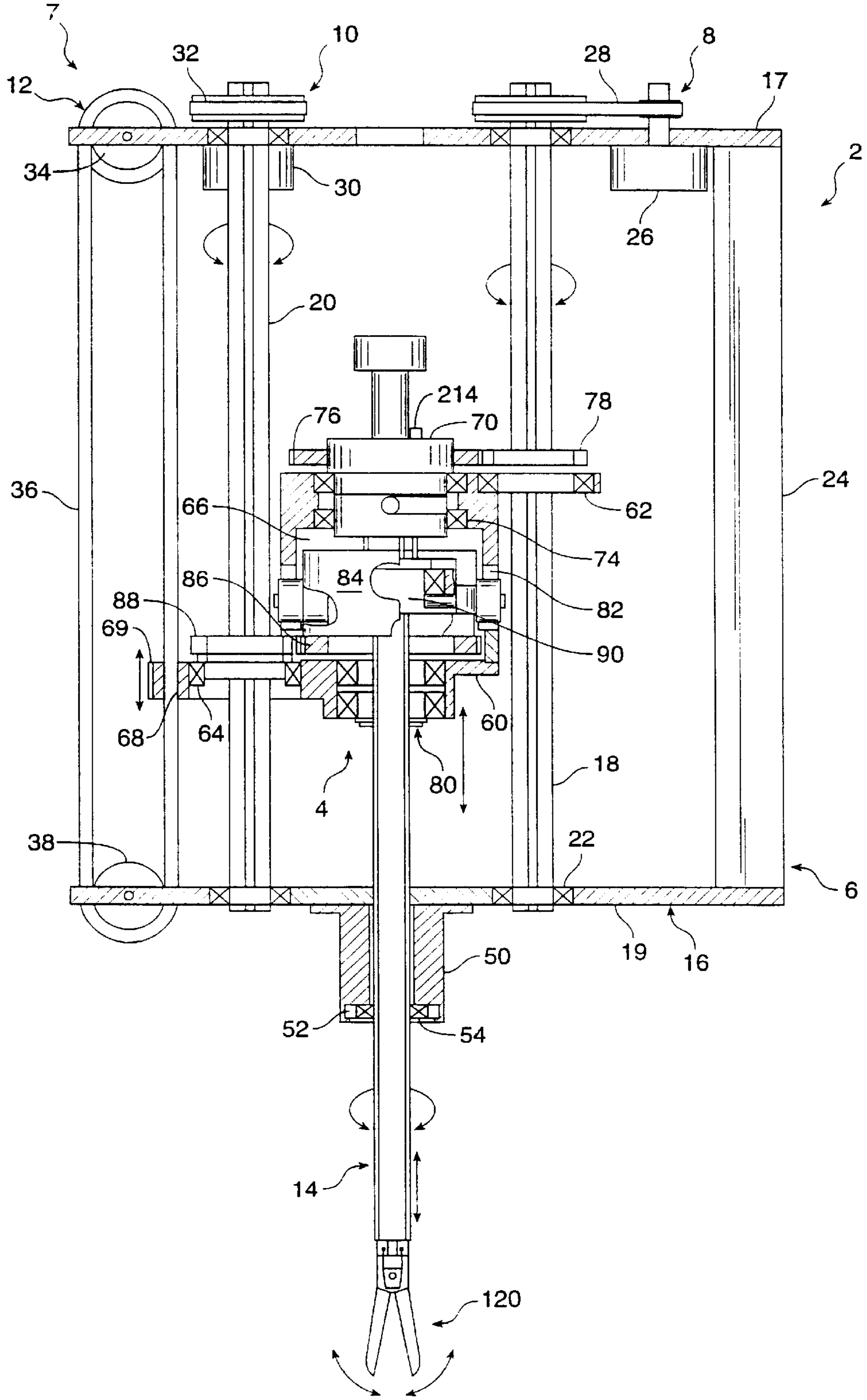

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FIG. 1

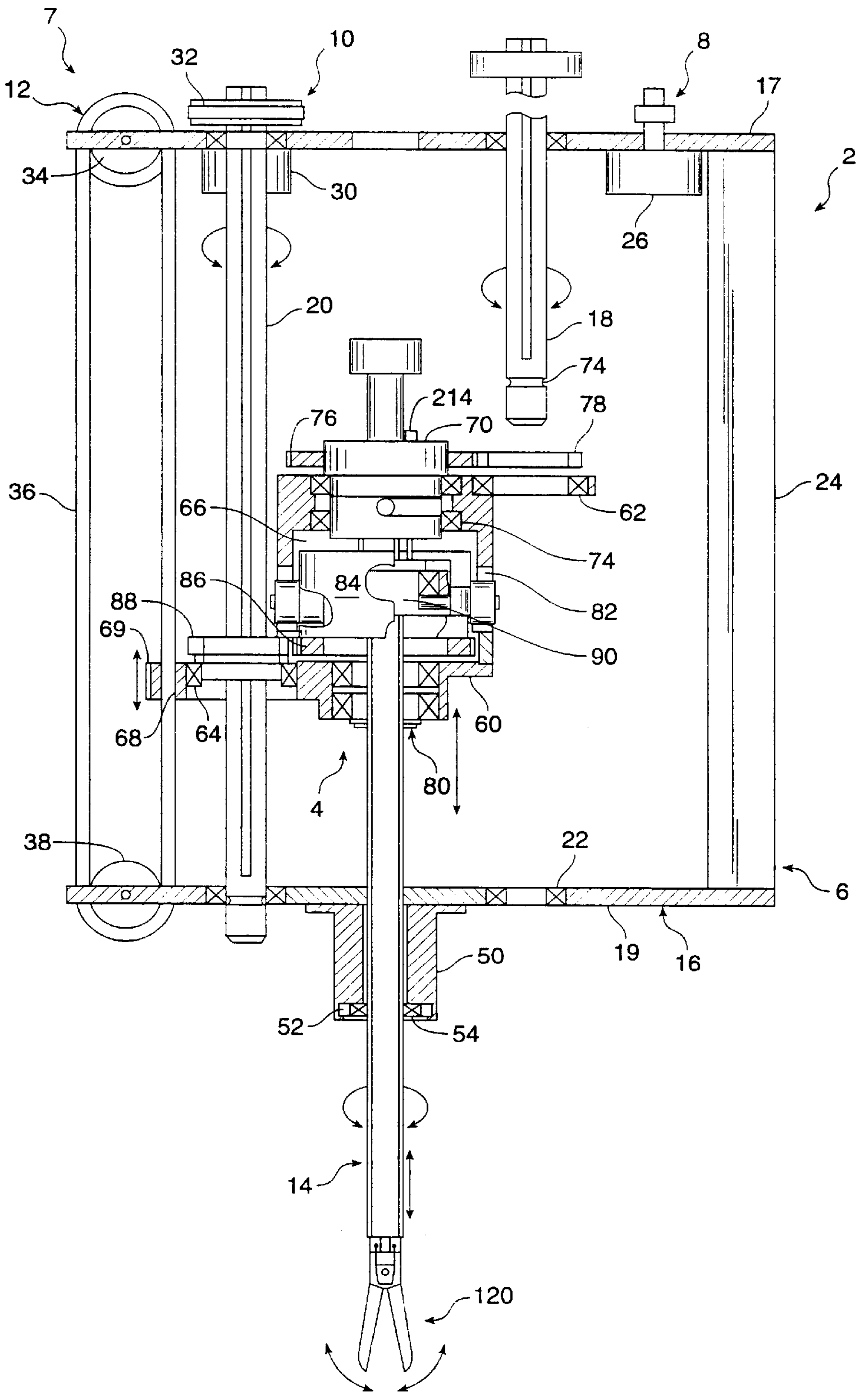
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FIG. 1A

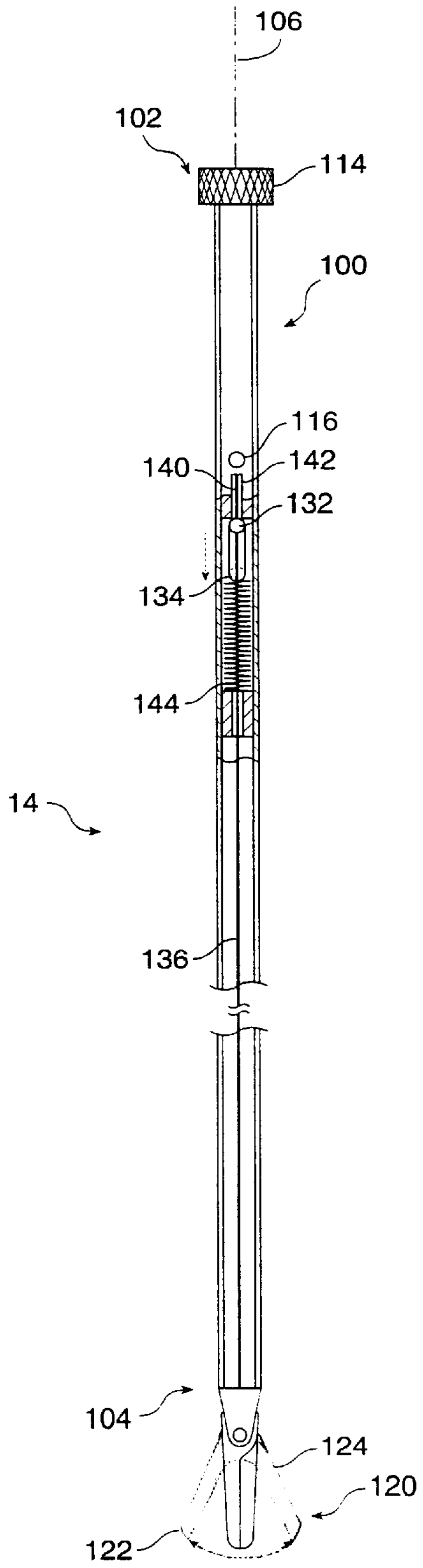
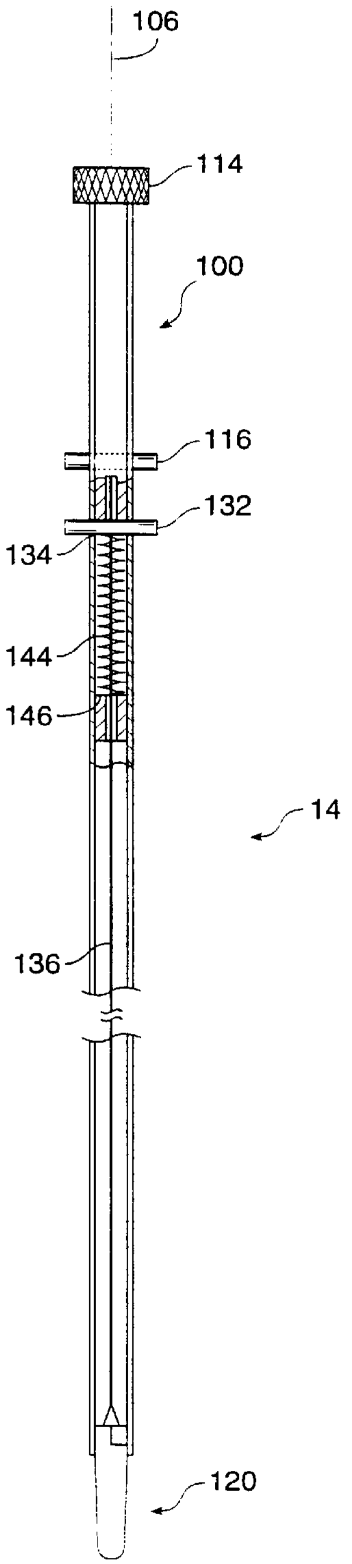


FIG. 2A



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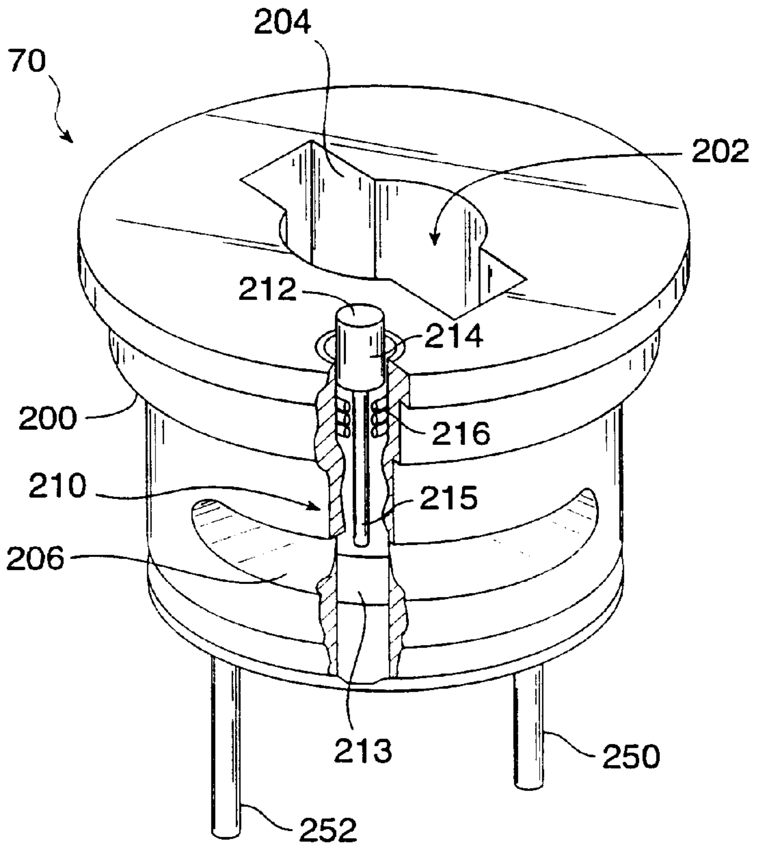
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FIG. 3A

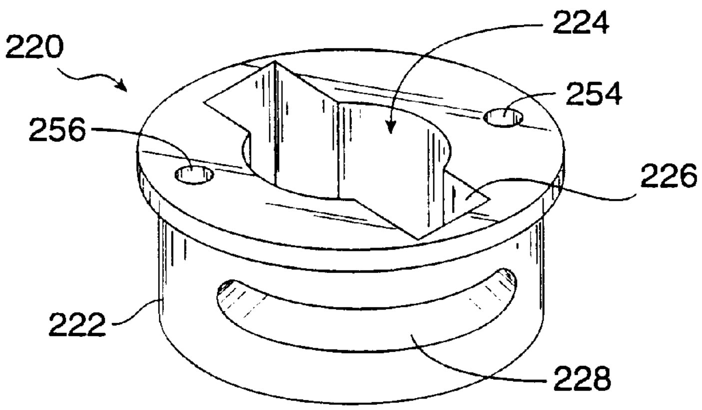
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FIG. 3B

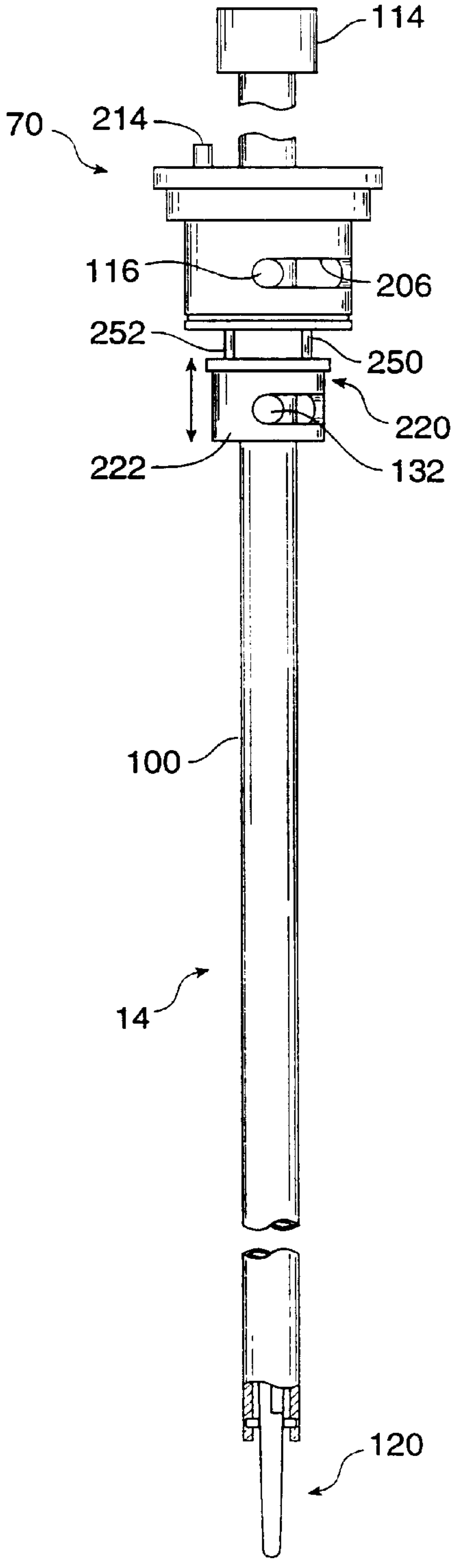

FIG. 4

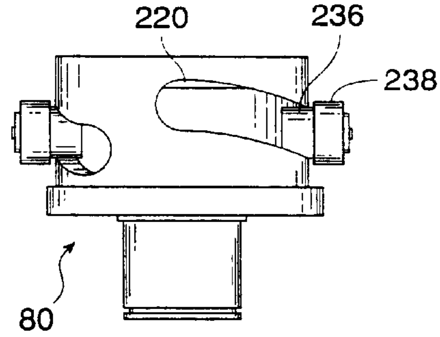

FIG. 5

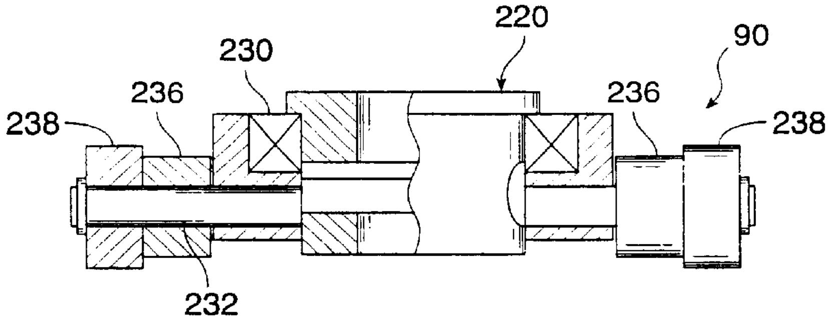

FIG. 6A

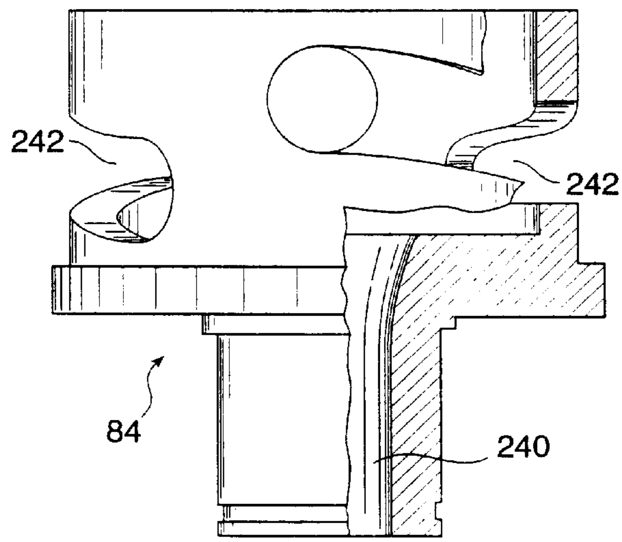

FIG. 6B

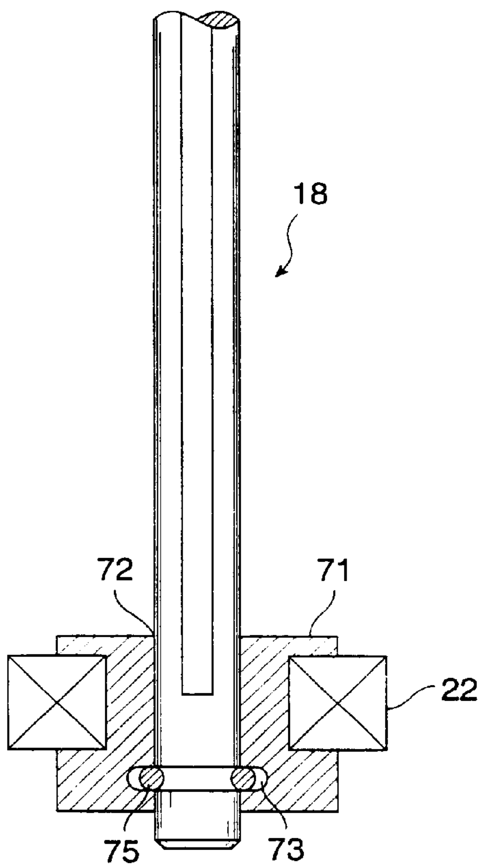

FIG. 7

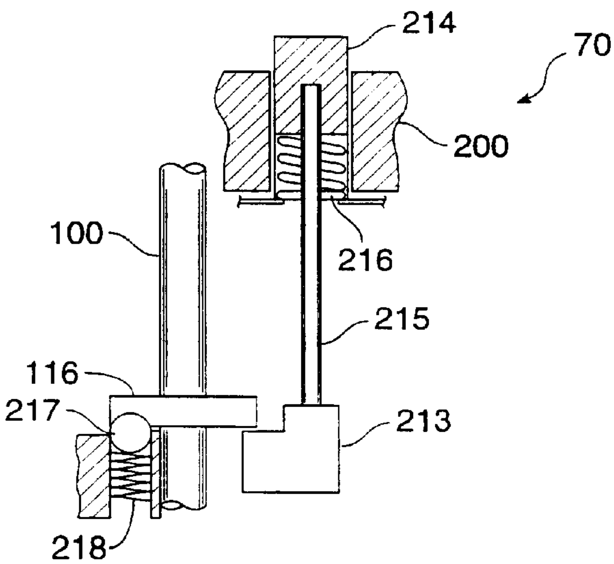

FIG. 8

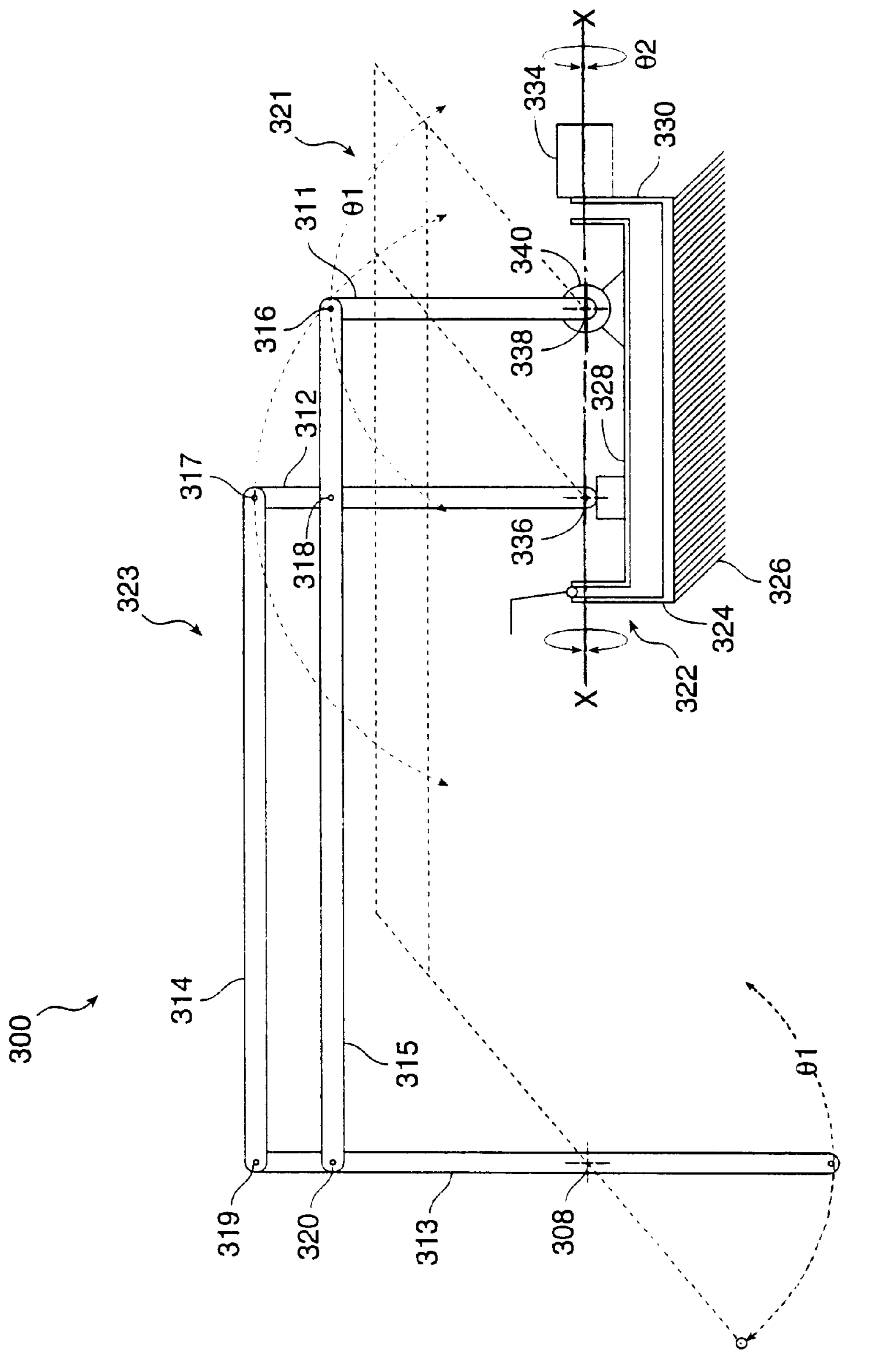
300
314
315
319
320
313
308
θ1
323
317
318
312
316
311
θ1
321
340
338
336
328
334
330
θ2
X
X
322
324
326

FIG. 9

SYSTEM AND METHOD FOR RELEASABLY HOLDING A SURGICAL INSTRUMENT

This application is a continuation of Ser. No. 09/105,706 filed Jun. 26, 1998, now U.S. Pat. No. 6,080,181, which is a Div. of Ser. No. 08/848,934 filed May 1, 1997 now U.S. Pat. No. 5,810,880, which is a CIP of 08/485,587 filed Jun. 7, 1995 now U.S. Pat. No. 5,649,956.

This invention was made with Government support under grant awarded by the National Institute of Health under Grant Number 5 R01 GM44902-02. The Government has certain rights in this invention.

BACKGROUND OF THE INVENTION

This invention relates to surgical manipulators and more particularly to robotic assisted apparatus for use in surgery.

In standard laparoscopic surgery, a patient's abdomen is insufflated with gas, and trocar sleeves are passed through small (approximately ½ inch) incisions to provide entry ports for laparoscopic surgical instruments. The laparoscopic surgical instruments generally include a laparoscope for viewing the surgical field, and working tools such as clamps, graspers, scissors, staplers, and needle holders. The working tools are similar to those used in conventional (open) surgery, except that the working end of each tool is separated from its handle by an approximately 12-inch long extension tube. To perform surgical procedures, the surgeon passes instruments through the trocar sleeves and manipulates them inside the abdomen by sliding them in and out through the sleeves, rotating them in the sleeves, levering (e.g., pivoting) the sleeves in the abdominal wall, and actuating end effectors on the distal end of the instruments.

In robotically-assisted and telerobotic surgery (both open surgery and endoscopic procedures), the position of the surgical instruments is controlled by servo motors rather than directly by hand or with fixed clamps. The servo motors follow the motions of a surgeon's hands as he/she manipulates input control devices at a location that may be remote from the patient. Position, force, and tactile feedback sensors may be employed to transmit position, force, and tactile sensations from the surgical instrument back to the surgeon's hands as he/she operates the telerobotic system.

The servo motors are typically part of an electromechanical device that supports and controls the surgical instruments that have been introduced directly into an open surgical site or through trocar sleeves into the patient's abdomen becomes a body cavity. During the operation, the electromechanical device or instrument holder provides mechanical actuation and control of a variety of surgical instruments, such as tissue graspers, needle drivers, etc, that each perform various functions for the surgeon, i.e., holding or driving a needle, grasping a blood vessel or dissecting tissue.

This new method of performing telesurgery through remote manipulation will create many new challenges. One such challenge is that different surgical instruments will be attached and detached from the same instrument holder a number of times during an operation. In laparoscopic procedures, for example, the number of entry ports into the patient's abdomen is generally limited during the operation because of space constraints as well as a desire to avoid unnecessary incisions in the patient. Thus, a number of different surgical instruments will typically be introduced through the same trocar sleeve during the operation. Likewise, in open surgery, there is typically not enough room around the surgical site to position more than one or two surgical manipulators, and so the surgeon's assistant will be compelled to frequently remove instruments from the holder and exchange them with other surgical tools.

What is needed, therefore, is an improved system and method for releasably coupling a surgical instrument to an instrument holder. The system should be configured to quickly and easily engage and disengage the instrument from the holder to minimize the instrument exchange time during endoscopic surgery. Preferably, the system is part of an electromechanical device that can be coupled to a controller mechanism to form a telerobotic system for operating the surgical instrument by remote control.

SUMMARY OF THE INVENTION

According to the invention, a system and method provide for releasably holding a surgical instrument during conventional open surgery or endoscopic procedures, such as laparoscopy. The instrument comprises an elongate shaft with proximal and distal ends and a mounting means having a protrusion extending radially from the shaft between the proximal and distal ends. An instrument holder comprises a support having a body with an axial passage for receiving the instrument shaft and a first hole in communication with the axial passage for receiving the protrusion. A second hole is cut into the body transversely to and in communication with the first hole so that the protrusion can be rotated within the second hole. To prevent the instrument from being accidently twisted and thereby disengaged from the instrument holder during surgery, the holder further includes a locking means coupled to the body for automatically locking the protrusion within the second hole thereby releasably locking the instrument to the instrument holder.

In a preferred configuration, the protrusion of the mounting means comprises a pair of opposing arms, such as mounting pins, extending outward from the instrument shaft. The first hole is an axially extending slot for receiving the mounting pins and the second hole is a perpendicular locking slot having a first portion aligned with the axial slot and a second portion extending circumferentially around the body of the instrument support. With this configuration, the mounting pins can be slid through the axial slot and rotated into the locking slot to attach the instrument to the holder. The instrument can be removed by performing the same two steps in reverse order. With this twist-lock motion, the surgeon can rapidly engage and disengage various instruments from the instrument holder during a surgical procedure.

The locking means preferably comprises a releasable latch assembly for locking the mounting pins to the instrument holder. The latch assembly includes a spring-loaded plunger coupled to a latch that normally locks the instrument in place by capturing the mounting pin in the locking slot. The plunger has a button extending outward from the instrument holder for moving the latch away from the locking slot. The button can be depressed manually or automatically to release the mounting pins and allow instrument exchange when the instrument is easily accessible to the surgeon.

The invention is particularly useful for releasably holding an endoscopic instrument configured for introduction through a small percutaneous penetration into a body cavity, e.g., the abdominal or thoracic cavity. To that end, the instrument preferably includes an end effector, such as a pair of jaws, coupled to the distal end for engaging a tissue structure within the body cavity. To actuate the end effector, the instrument has a second pair of arms, such as actuator pins, laterally extending from the shaft and operatively coupled to the end effector. Preferably, the actuator pins are axially displaceable with respect to the shaft to actuate the end effector (e.g., open and close the jaws). The instrument holder further includes an actuator driver releasably coupled to the actuator arms and to an external driver for actuating the end effector. The actuator driver preferably includes a twist-lock interface having transverse slots similar to that described for the instrument support so that the instrument can be simultaneously engaged or disengaged from both the instrument support and the actuator driver.

Other features and advantages of the invention will appear from the following description in which the preferred embodiment has been set forth in detail in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial sectional elevational view of a robotic endoscopic surgical instrument mounted to a manipulator assembly according to the present invention;

FIG. **1**A is a partial sectional elevational view of the manipulator assembly of FIG. **1** illustrating the removal of an instrument holder from the rest of the assembly;

FIGS. **2**A and **2**B are enlarged side and front cross-sectional views, respectively, of the surgical instrument of FIG. **1**;

FIGS. **3**A and **3**B are perspective views of an instrument support and an actuator pin catch, respectively, for releasably mounting the surgical instrument to the manipulator assembly;

FIG. **4** is a front elevational view of the surgical instrument mounted within the instrument support and actuator pin catch of FIGS. **3**A and **3**B;

FIG. **5** is a front elevational view of an actuator driver for providing axial movement of the actuator pin catch of FIG. **3**B;

FIGS. **6**A and **6**B are enlarged cross-sectional views of an actuator carriage assembly and a helical actuator of the actuator driver of FIG. **5**;

FIG. **7** is an enlarged detail of a portion of the frame of the manipulator assembly of FIG. **1** illustrating a coupling mechanism for removing the shafts from the frame;

FIG. **8** is a partial cross-sectional view of the instrument support of FIG. **3**A illustrating a locking mechanism for a twist lock interface according to the present invention; and

FIG. **9** is an elevational view of a remote center positioner for holding the manipulator assembly of FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings in detail, wherein like numerals indicate like elements, a manipulator assembly **2** is illustrated according to the principles of the invention. Manipulator assembly **2** generally includes an instrument holder **4** removably mounted to a base **6** and a drive assembly **7** for manipulating a surgical instrument **14** releasably coupled to instrument holder **4**.

Referring to FIG. **1**, base **6** comprises a frame **16** having proximal and distal elongate support members **17**, **19** and first and second ball-spline shafts **18**, **20** rotatably coupled to support members **17**, **19** via bearings **22**. Frame **16** further includes a support bracket **24** for attaching manipulator assembly **2** to a remote center positioner **300**, as discussed in more detail below (see FIG. **9**). Drive assembly **7** comprises first, second and third drives **8**, **10**, **12**, which are mounted to frame **16** and configured to provide three degrees of freedom to surgical instrument **14**. In the preferred embodiment, first drive **8** rotates instrument **14** around its own axis, second drive **10** actuates an end effector **120** on the distal end of instrument **14** and third drive **12** axially displaces instrument **14** with respect to frame **16**. Of course, it will be readily recognized by those skilled in the art that other configurations are possible. For example, assembly **2** may include additional drives for providing additional degrees of freedom to surgical instrument **14**, such as rotation and flexion of an instrument wrist.

First drive **8** comprises a rotation drive motor **26** fixed to frame **16** and coupled to first shaft **18** by a drive belt **28** for rotating first shaft **18** with respect to frame **16**. Second drive **10** comprises a gripper drive motor **30** fixed to frame **16** and coupled to second shaft **20** by a drive belt **32** for rotating second shaft **20** with respect to frame **16**. Third drive **12** comprises a vertical drive motor **34** coupled to instrument holder **4** via a drive belt **36** and two pulleys **38** for axially displacing instrument holder **4** with respect to frame **16**. Drive motors **26**, **30**, **34** are preferably coupled to a controller mechanism via servo-control electronics (not shown) to form a telerobotic system for operating surgical instrument **14** by remote control. The drive motors follow the motions of a surgeon's hands as he/she manipulates input control devices at a location that may be remote from the patient. A suitable telerobotic system for controlling the drive motors is described in commonly assigned co-pending application Ser. No. 08/823,932 filed Jan. 21, 1992 TELEOPERATOR SYSTEM AND METHOD WITH TELEPRESENCE, which is incorporated herein by reference.

The above described telerobotic servo system preferably has a servo bandwidth with a 3 dB cut off frequency of at least 10 hz so that the system can quickly and accurately respond to the rapid hand motions used by the surgeon. To operate effectively with this system, instrument holder **4** has a relatively low inertia and drive motors **26**, **30**, **34** have relatively low ratio gear or pulley couplings.

In a specific embodiment, surgical instrument **14** is an endoscopic instrument configured for introduction through a percutaneous penetration into a body cavity, such as the abdominal or thoracic cavity. In this embodiment, manipulator assembly **2** supports a cannula **50** on distal support member **19** of frame **16** for placement in the entry incision during an endoscopic surgical procedure (note that cannula **50** is illustrated schematically in FIG. **1** and will typically be much longer). Cannula **50** is preferably a conventional gas sealing trocar sleeve adapted for laparoscopic surgery, such as colon resection and Nissen fundoplication.

As shown in FIG. **1**, cannula **50** preferably includes a force sensing element **52**, such as a strain gauge or force-sensing resistor, mounted to an annular bearing **54** within cannula **50**. Bearing **54** supports instrument **14** during surgery, allowing the instrument to rotate and move axially through the central bore of bearing **54**. Bearing **54** transmits lateral forces exerted by the instrument **14** to force sensing element **52**, which is operably connected to the controller mechanism for transmitting these forces to the input control devices (not shown) held by the surgeon in the telerobotic system. In this manner, forces acting on instrument **14** can be detected without disturbances from forces acting on cannula **50**, such as the tissue surrounding the surgical incision, or by gravity and inertial forces acting on manipulator assembly **2**. This facilitates the use of manipulator assembly in a robotic system because the surgeon will directly sense the forces acting against the end of instrument

14. Of course, the gravitational forces acting on the distal end of instrument **14** will also be detected by force sensing element **52**. However, these forces would also be sensed by the surgeon during direct manipulation of the instrument.

As shown in FIG. **1**, instrument holder **4** comprises a chassis **60** mounted on shafts **18, 20** via ball-spline bearings **62, 64** so that chassis **60** may move axially with respect to shafts **18, 20**, but is prevented from rotating with shafts **18, 20**. Chassis **60** is preferably constructed of a material that will withstand exposure to high temperature sterilization processes, such as stainless steel, so that chassis **60** can be sterilized after a surgical procedure. Chassis **60** includes a central cavity **66** for receiving surgical instrument **14** and an arm **68** laterally extending from chassis **60**. Arm **68** is fixed to drive belt **36** so that rotation of drive belt **36** moves instrument holder **4** in the axial direction along shafts **18, 20**.

Instrument holder **4** is removably coupled to base **6** and the drive motors so that the entire holder **4** can be removed and sterilized by conventional methods, such as steam, heat and pressure, chemicals, etc. In the preferred configuration, arm **68** includes a toggle switch **69** that can be rotated to release arm **68** from drive belt **36** (FIG. **1**). In addition, shafts **18, 20** are removably coupled to bearings **22** so that the shafts can be axially withdrawn from support members **17, 19** of frame **16**, as shown in FIG. **1**A. To this end, the distal bearings **22** preferably include a coupling mechanism for allowing the removal of shafts **18, 20**. As shown in FIG. **7**, distal support member **19** includes a support collar **71** within each distal bearing **22** having an inner bore **72** for passage of one of the shafts **18, 20**. Each support collar **71** has an internal groove **73** and shafts **18, 20** each have an annular groove **74** (see FIG. **1**A) near their lower ends that is aligned with internal grooves **73** when the shafts are suitably mounted within frame **16** (FIG. **1**). A spring clip **75** is positioned within each internal groove **73** to hold each shaft **18, 20** within the respective support collar **71**. Spring clip **74** has a discontinuity (not shown) to allow removal of shafts **18, 20** upon the application of a threshold axial force on the shafts.

To remove instrument holder **4** from base **6**, the operator rotates toggle switch **69** to release arm **68** from drive belt **36** and removes drive belts **28, 32** from drives **8, 10**. As shown in FIG. **1**A, the operator holds instrument holder **4** and pulls shafts **18, 20** upwards, providing enough force to release spring clips **75**. Shafts **18, 20** will disengage from distal bearings **22** and slide through ball-spline bearings **62, 64** so that instrument holder **4** is disconnected from base **6**. It should be understood that the invention is not limited to the above described means for removably coupling instrument holder **4** to base **6** and drive assembly **7**. For example, distal support member **19** may be removably coupled to the rest of frame **16** so that the surgeon simply removes member **19** and slides holder down and off shafts **18, 20**. Proximal support member **17** may be removably coupled to frame **16** in a similar manner. Alternatively, the drive motors may be housed in a separate servo-box (not shown) that is removably attached to base **6**. In this configuration, the servo-box would be removed from base **6** so that the entire base **6**, together with holder **4**, can be sterilized.

The lower portion of base **6** (including distal support member **19**) may also be sterilized to decontaminate those parts that come into contact with holder **4** or instrument **14** (e.g., by dipping the lower portion of base **6** into a sterilizing bath). To facilitate this type of sterilization, shafts **18, 20** will preferably be somewhat longer than shown in FIG. **1** so that the upper portion of base **6**, including drive assembly **7**, is disposed sufficiently away from holder **4** and instrument **14**. In this manner, the surgical manipulator can be easily sterilized after a surgical procedure without damaging the drive motors or the electrical connections required for the telerobotic system.

Instrument holder **4** further includes an instrument support **70** (see detail in FIG. **3**A), for releasably coupling surgical instrument **14** to the manipulator assembly. Instrument support **70** is rotatably mounted within chassis **60** via mounting bearings **74** so that support **70** and the instrument can be rotated therein. As shown in FIG. **1**, support **70** is circumscribed by an annular ring gear **76** having teeth that mesh with the teeth of a drive gear **78** mounted to first-shaft **18**. Drive gear **78** is configured around first shaft **18** such that it will rotate with first shaft **18**, thereby rotating instrument support **70** and the surgical instrument therewith. Drive gear **78** is also configured to move axially with respect to first shaft **18** to allow axial movement of instrument holder **4** with respect to frame **16**.

Instrument holder **4** further includes an actuator driver **80** (see detail in FIG. **5**) movably mounted within axial guide slots **82** on either side of chassis **60**. Actuator driver **80** comprises a helical actuator **84** (see detail in FIG. **6**B) having a ring gear **86** that meshes with a gripper drive gear **88** mounted to second shaft **20**. Rotation of second shaft **20** causes rotation of gripper drive gear **88**, thereby rotating ring gear **86** and helical actuator **84** within chassis **60**. Actuator driver **80** further includes an actuator carriage assembly **90** (see detail in FIG. **6**A) for releasably coupling an end effector actuator of surgical instrument **14** to instrument holder **4** (see FIG. **2**). Carriage assembly **90** is mounted within helical actuator **84** and chassis **60** such that rotation of helical actuator **84** causes a corresponding axial movement of carriage assembly **90** with respect to chassis **60**, as discussed in greater detail below.

FIGS. **2**A and **2**B illustrate a specific embodiment of an endoscopic surgical instrument **14** capable of being operated by a motorized manipulator, such as manipulator assembly **2**, for telerobotic surgery. Surgical instrument **14** can be a variety of conventional endoscopic instruments adapted for delivery through a percutaneous penetration into a body cavity, such as tissue graspers, needle drivers, microscissors, electrocautery dissectors, etc. In the preferred embodiment, instrument **14** is a tissue grasper comprising a shaft **100** having a proximal end **102**, a distal end **104** and a longitudinal axis **106** therebetween. A knurled handle **114** is attached to proximal end **102** of shaft **100** to facilitate manipulation of instrument **14**.

Shaft **100** is preferably a stainless steel tube having an outer diameter in the range of 2–10 mm, usually 4–8 mm, so as to fit within a cannula having an internal diameter in the range of 2–15 mm. Shaft **100** can also be introduced directly through a percutaneous incision in the patient. Shaft **100** has a length selected to reach a target site in a body cavity, such as the abdomen, and to extend sufficiently out of the body cavity to facilitate easy manipulation of surgical instrument **14**. Thus, shaft **100** should be at least between 10 cm and 40 cm and is preferably between 17 cm and 30 cm. It should be noted that although shaft **100** is shown as having a circular cross-sectional shape in the drawings, shaft **100** could alternatively have a rectangular, triangular, oval or channel cross-sectional shape.

In a specific configuration, shaft **100** includes a mounting means for releasably coupling surgical instrument **14** to instrument support **70** and first drive **8** of manipulator assembly **2**. In the preferred embodiment, mounting means comprises a pair of opposed mounting pins **116** extending laterally outward from shaft **100**. Mounting pins **116** are rigidly connected to shaft **100** and are adapted for engaging a twist-lock interface on instrument support **70**, as discussed in detail below. It should be understood that the invention is not limited to a pair of opposing pins and mounting means can include a single mounting pin or a plurality **6**f pins extending circumferentially around shaft. Alternatively, pins **116** may have a variety of other shapes, such as spherical or annular, if desired.

Instrument **14** includes an end effector **120** extending from distal end **104** for engaging a tissue structure on the patient, such as the abdomen during laparoscopic surgery. In the preferred embodiment, end effector **120** comprises a pair of jaws **122, 124** that are movable between open and closed positions for grasping a blood vessel, holding a suture, etc. Jaws **122, 124** preferably have transverse grooves or other textural features (not shown) on opposing surfaces to facilitate gripping of the tissue structure. To avoid the possibility of damaging the tissue to which jaws **122, 124** are applied, the jaws may also include atraumatic means (not shown), such as elastomeric sleeves made of rubber, foam or surgical gauze wrapped around jaws **122, 124**.

To move jaws **122, 124** between the open and closed positions, instrument **14** includes an end effector actuator releasably coupled to actuator driver **80** and second drive **10** of manipulation assembly **2** (see FIG. **4**). In the preferred embodiment, end effector actuator comprises a pair of opposed actuator pins **132** laterally protruding from axially extending slots **134** in shaft **100**. Actuator pins **132** are coupled to an elongate rod **136** slidably disposed within an inner lumen **138** of shaft **100**. Actuator pins **132** are slidable within slots **134** so that rod **136** is axially movable with respect to shaft **100** and mounting pins **116** to open and close jaws **122, 124**, as is conventional in the art. Elongate rod **136** has a proximal portion **140** that is disposed within an inner lumen **142** within shaft **100** to prevent actuator pins **132** from moving in the laterally direction and to ensure that rod **136** remains. generally centered within shaft **100** during a surgical procedure.

Jaws **122, 124** are preferably biased into the closed positioned by an annular compression spring **144** positioned within shaft **100** between actuator pins **132** and an annular disc **146** fixed to the inside surface of shaft **100**. During endoscopic procedures, this allows the surgical team to introduce jaws **122, 124** through cannula **50** (or any other type of percutaneous penetration) and into the body cavity without getting stuck within cannula **50** or damaging surrounding tissue.

FIGS. **3**A, **3**B and **4** illustrate a twist lock mechanism for releasably connecting surgical instrument **14** to manipulator assembly **2** so that different instruments may be rapidly changed during an endoscopic surgical procedure. As shown in FIG. **3**A, instrument support **70** comprises an annular collar **200** defining a central bore **202** for receiving shaft **100** of surgical instrument **14**. Collar **200** further defines an axially extending slot **204** in communication with bore **202** and sized to allow mounting and actuator pins **116, 132** of instrument **14** to slide therethrough (see FIG. **4**). Two locking slots **206** are cut into annular collar **200** at a transverse angle, preferably about 90°, to axially extending slot **204** (note that only one of the locking slots are shown in FIG. **3**A). Locking slots **206** intersect slot **204** near the center of annular collar **200** and extend circumferentially around bore **202**, preferably about 90°, to allow rotation of both mounting pins **116** therethrough, as discussed below.

As shown in FIGS. **3**A and **8**, instrument support **70** further comprises means for locking mounting pins **116** into locking slots **206** so that the instrument cannot be accidently twisted and thereby disengaged from instrument support **70** during surgery. Preferably, the locking means comprises a latch assembly having a plunger **210** slidably disposed within a hole **212** in collar **200**, as shown in FIG. **3**A. Plunger **210** comprises an L-shaped latch **213** coupled to a release button **214** by a rod **215** extending through hole **212**. Plunger **210** is movable between a first position, where latch **213** is not disposed within locking slots **206** so that mounting pins **116** are free to rotate therethrough, and a second position, where latch **213** is at least partially disposed within one of the locking slots **206** so as to prevent rotation of mounting pins **116**. Latch **213** is preferably biased into the second or locked position by a compression spring **216**.

Button **214** is disposed on the upper surface of support **70** for manual actuation by the surgeon or automatic actuation by base **6**. Preferably, when instrument holder **4** is moved to its most proximal position (see FIG. **1**), proximal support member **17** of frame **16** depresses release switch **214** to move latch **213** into the first or open position. With this configuration, instruments can be exchanged only when the instrument holder **4** is in the most proximal position, where shaft **100** of instrument **14** is easily accessible. In addition, this prevents the accidental release of the instrument when its distal end has penetrated cannula **50** and is disposed within the body cavity.

The intersecting axial and locking slots **204, 206** form an interface for releasably coupling mounting pins **116** of surgical instrument **14** to instrument holder **4**. To insert instrument **14**, the surgeon aligns mounting pins **116** with axial slot **204** and slides the instrument through bore **202** of annular collar **200** until mounting pins **116** are aligned with locking slots **206**, as shown in FIG. **4**. The instrument is then rotated a sufficient distance, preferably about a ¼ turn, through locking slots **206** so that the pins are no longer aligned with axial slot **204**. When instrument **14** is moved distally, switch **214** is released (FIG. **1**) and latch **213** moves into locking slots **206** to prevent mounting pins **116** from rotating back into alignment with axial slot **204** so that instrument **14** is secured to instrument support **70**. It should be noted that a single mounting pin may be utilized with the above described configuration to lock the surgical instrument to the support. However, two opposing pins are preferred because this configuration reduces torsional forces on the inner surface of locking slots **206**.

As shown in FIG. **8**, the locking means preferably includes a ball detent **217** disposed within collar **200**. Ball detent **217** is biased upward into one of the locking slots **206** by a spring **218**. Ball detent **217** serves to temporarily capture mounting pins **116** in a position rotated about 90° from alignment with axial slot **204**. This ensures that the mounting pins will be completely rotated into the proper position (i.e., out of the way of latch **213**) when instrument **14** is twisted into instrument holder. Otherwise, when switch **214** is released, latch **213** could become engaged with mounting pins **216** so that the latch is unable to move completely into the locked position, thereby potentially causing the accidental release of instrument **14** during surgery.

As shown in FIGS. **3**B, **4** and **5**, actuator driver **80** of instrument holder **4** further comprises an actuator pin catch **220** for releasably holding and moving actuator pins **132** of instrument **14**. Actuator pin catch **220** is constructed similarly to instrument support **70** (FIG. **3**A), comprising an annular collar **222** that defines a bore **224** for receiving shaft **100** and an axially extending slot **226** for receiving actuator pins **132**. A locking slot **228** is cut into actuator pin catch **220** at a 90° angle so that actuator pins can be rotated into the lock slot to couple actuator pins **132** to actuator driver **66**, as discussed above in reference to the mounting pins. It should be noted that slot **226** need not extend completely through collar **222** since actuator pins **132** are located distally of mounting pins **116** (the instrument is preferably inserted jaws first). Of course, actuator and mounting pins **132**, **116** may be reversed so that the mounting pins are distal to the actuator pins, if desired.

Referring to FIG. **6**A, actuator pin catch **220** is rotatably mounted on a ball bearing **230** in actuator carriage assembly **90**. Bearing **230** allows the pin catch **220** to rotate freely in carriage assembly **90** while preventing relative axial motion. Therefore, when instrument **14** is rotated by first drive **8**, actuator pins **132** will rotate within carriage assembly **90**. Carriage assembly **90** further comprises two sets of axles **232** for rotatably supporting a pair of inner rollers **236** and a pair of outer rollers **238**. As shown in FIG. **1**, outer rollers **238** are slidably disposed within axial guide slots **82** of chassis **60** to prevent rotation of carriage assembly **90** with respect to chassis **60**. Inner and outer rollers **236**, **238** cooperate with helical actuator **84** and chassis **60** of instrument holder **4** to move axially with respect to the holder, thereby axially moving pin catch **220** and actuator pins **132** therewith relative to shaft **100** of instrument **14** (which actuates jaws **122**, **124**, as discussed above).

As shown in FIG. **6**B, helical actuator **84** includes a central bore **240** for receiving carriage assembly **90** and surgical instrument **14** and two opposing helical tracks **242**, **244** each extending circumferentially around helical actuator **84** (preferably slightly less than 180°) for receiving inner rollers **236** of carriage assembly **90**, as shown in FIG. **5**. With outer rollers **238** constrained in axial guide slots **82** of chassis **60**, rotation of helical actuator **84** causes carriage assembly **90** (and actuator pin catch **220**) to move up or down, depending on the sense of the rotation. Because of the symmetrical design of helical actuator **84**, the actuation force applied by second driver **10** will not generate any effective side loads on instrument **14**, which avoids frictional coupling with other degrees of freedom such as axial (third driver **12**) and rotation (first driver **8**). In the preferred embodiment, helical tracks **242**, **244** have a pitch selected such that the mechanism can be easily back-driven, allowing grip forces to be sensed in a position-servoed teleoperation system.

As shown in FIGS. **3**A and **3**B, instrument holder **4** further includes a pair of axial guide pins **250**, **252** fixed to instrument support **70**. Actuator pin catch **220** has a pair of openings **254**, **256** for receiving guide pins **250**, **252**. Guide pins **250**, **252** prevent relative rotation between pin catch **220** and support **70** (so that actuator and mounting pins **116**, **132** can both rotate with the instrument) and allow axial movement relative to each other (so that end effector **120** can be actuated by axial movement of actuator pins **132**).

FIG. **9** is an elevational view of a remote center positioner **300** which can be used to support manipulator assembly **2** above the patient (note that support manipulator **2** is not shown in FIG. **8**). Remote center positioner **300** provides two degrees of freedom for positioning manipulator assembly **2**, constraining it to rotate about a point **308** coincident with the entry incision. Preferably, point **308** will be approximately the center of bearing **54** in cannula **50** (FIG. **1**). A more complete description-of remote center positioner **300** is described in commonly assigned co-pending application Ser. No. 08/062,404 filed May 14, 1993 REMOTE CENTER POSITIONER, which is incorporated herein by reference.

A first linkage means is indicated generally by the numeral **321** and a second linkage in the form of a parallelogram is indicated by the numeral **323**. The first linkage means is pivotally mounted on a base plate for rotation about an x—x axis. The second linkage means is pivotally connected to the first linkage means and is adapted to move in a plane parallel to the first linkage. Five link members (including extensions thereof), **311**, **312**, **313**, **314**, and **315** are connected together with pivot joints **316**–**320**. A portion of element **313** extends beyond pivot **320** of the parallelogram linkage. The parallelogram linkage has an operating end at link member **313** and a driving end at link member **312**. The elongated element **313** may, as desired later, carry a surgical instrument or other device, such as support bracket **24** of manipulator assembly **2**. The pivot joints allow relative motion of the link members only in the plane containing them.

A parallelogram linkage is formed by corresponding link members **314**, **315** and link members **312** and **313**. The portions of link members **314** and **315** of the parallelogram are of equal length as are the portions of members **312** and **313** of the parallelogram. These members are connected together in a parallelogram for relative movement only in the plane formed by the members. A rotatable joint generally indicated by the numeral **322** is connected to a suitable base **324**. The rotatable joint **322** is mounted on a base plate **326** adapted to be fixedly mounted to the base support means **324**. A pivot plate **328** is pivotally mounted to base plate **326** by suitable means at, such as, pivots **330**, **332**. Thus pivot plate **328** may be rotated about axis x—x through a desired angle θ2. This may be accomplished manually or by a suitable pivot drive motor **334**.

A first linkage is pivotally mounted on the pivot plate **328** of the rotatable joint **322**. The linkage elements **311**, **312** and the link members are relatively stiff or inflexible so that they may adequately support an instrument used in surgical operations. Rods made of aluminum or other metal are useful as such links. The linkage elements **311** and **312** are pivotally mounted on base plate **328** for rotation with respect to the rotatable joint by pivots **336** and **338**. At least one of the pivots **336**, **338** is positioned so that its axis of rotation is normal to and intersects the x—x axis. Movement may occur manually or may occur using a linkage drive motor **340**. The first linkage is also shaped in the form of a parallelogram formed by linkage elements **311**, and **312**; the portion of link member **315** connected thereto by pivots **316**, **318**; and base plate **328**. One of the link members **315** is thus utilized in both the first **321** and second **323** linkage means. Linkage element **312** also forms a common link of both the first linkage means **321** and the second linkage means **323**. In accordance with the invention, a remote center of spherical rotation **308** is provided by the above described embodiment of apparatus when the linkage element **311** is rotated and/or when pivot plate **328** is rotated about axis x—x. Thus, the end of element **313** can be moved through desired angles θ1 and θ2 or rotated about its own axis while the remote center of rotation remains at the same location.

FIG. **9** also shows an inclinometer **350** attached to the base of remote center positioner **300**. The remote center positioner may be mounted at an arbitrary orientation with respect to vertical depending on the particular surgery to be performed, and inclinometer **350** can be used to measure this orientation. The measured orientation can be used to calculate and implement servo control signals necessary to control the telerobotic system so as to prevent gravitational forces acting on the system mechanisms from being-felt by the surgeon.

Variations and changes may be made by others without departing from the spirit of the present invention. For example, it should be understood that the present invention is not limited to endoscopic surgery. In fact, instrument holder **4**, along with a telerobotic control. mechanism, would be particularly useful during open surgical procedures, allowing a surgeon to perform an operation from a remote location, such as a different room or a completely different hospital.

What is claimed is:

1. A surgical method comprising:

releasably coupling a surgical instrument to an instrument holder, the surgical instrument comprising an elongate shaft with proximal and distal ends, a longitudinal axis therebetween, and an end effector on the distal end;

locking the instrument to the instrument holder;

coupling a drive assembly of a manipulator to the surgical instrument with the holder;

manipulating the instrument holder and the surgical instrument with the manipulator; and

transferring at least two motion actuations from the drive assembly to the surgical instrument with the holder, the motion actuations including rotation of the instrument about the longitudinal axis and actuation of the end effector.

2. The surgical method of claim **1** further comprising rotating the instrument about the instrument axis with a first controllable motor of the drive assembly, actuating the end effector on the instrument with a second controllable motor of the drive assembly, axially translating the instrument with a third controllable motor of the drive assembly, and transferring motion actuation from the third motor to the instrument with the instrument holder.

3. The surgical method of claim **1** further comprising transferring electrical signals between the manipulator assembly and the instrument with one or more electrical feed-throughs of the instrument holder.

4. The surgical system of claim **1** further comprising remotely controlling the surgical instrument with an input control device located remotely from said surgical instrument using a servomechanism coupling the instrument holder and the input control device.

5. A method for performing a surgical procedure, the method comprising:

releasably coupling an instrument holder to a surgical instrument, the surgical instrument comprising a proximal end, a distal end, a longitudinal axis therebetween, and an end effector disposed at the distal end; and

manipulating the instrument holder and surgical instrument with a manipulator assembly to transfer at least two motions to the surgical instrument including spinning the surgical instrument about the longitudinal axis and actuating the end effector.

6. The method of claim **5** comprising axially translating the instrument along the longitudinal axis.

7. The method of claim **5** wherein releasably coupling comprises engaging a coupling interface of the instrument holder with a mounting interface of the surgical instrument.

8. The method of claim **5** comprising locking the surgical instrument to the instrument holder.

9. The method of claim **5** comprising mechanically coupling a drive assembly to the surgical instrument.

10. The method of claim **9** wherein manipulating comprises actuating the drive assembly.

11. The method of claim **10** wherein actuating comprises activating an input device that is remote from the surgical instrument.

12. The method of claim **5** comprising removing the surgical instrument from the instrument holder and replacing the surgical instrument with a second surgical instrument during a surgical procedure.

13. The method of claim **5** wherein the surgical instrument comprises a needle driver, electrocautery dissector, clamp, stapler, grasper, scissors, or needle holder.

* * * * *

patsnap

专利名称(译)	用于可释放地保持手术器械的系统和方法		
公开(公告)号	US6461372	公开(公告)日	2002-10-08
申请号	US09/521253	申请日	2000-03-08
[标]申请(专利权)人(译)	斯坦福研究院		
申请(专利权)人(译)	SRI国际公司		
当前申请(专利权)人(译)	SRI国际公司		
[标]发明人	JENSEN JOEL F HILL JOHN W		
发明人	JENSEN, JOEL F. HILL, JOHN W.		
IPC分类号	A61B19/00 B25J15/04 B25J18/04 B25J18/00 B25J9/10 A61B17/00 A61B17/28		
CPC分类号	B25J9/1065 B25J15/04 B25J18/04 A61B19/22 A61B17/29 Y10T403/581 A61B2017/00464 A61B2017/2932 A61B2019/223 A61B2019/2234 A61B2019/2242 A61B2019/2292 A61B2019/265 A61B2017/00477 Y10T403/587 A61B34/35 A61B34/70 A61B34/71 A61B34/76 A61B2034/305 A61B2090/506		
代理机构(译)	TOWNSEND和TOWNSEND和机组LLP		
外部链接	Espacenet USPTO		

摘要(译)

本发明涉及一种用于可释放地保持外科器械（14）的系统和方法，所述外科器械（14）例如是内窥镜器械，其配置成通过患者体内的小的经皮穿透来递送。该器械包括细长轴（100），该细长轴具有一对安装销（116），所述安装销（116）在其近端和远端之间从轴横向延伸。仪器支架包括支撑件，该支撑件具有中心孔（202）和轴向延伸的槽（204），用于接收器械轴和安装销。一对锁定槽（206）横向于轴向槽切入支撑件并与轴向槽连通，使得安装销可在锁定槽内旋转。器械支撑件还包括闩锁组件，用于自动地将安装销锁定在锁定槽内，以将器械可释放地连接到器械保持器。通过这种扭锁操作，外科医生可以在外科手术过程中快速地接合和脱离各种器械，例如开放手术，腹腔镜检查或胸腔镜检查。