DEVELOPMENT OF ROBOTS FROM ROBOTIC SURGERY TO MINIMALLY INVASIVE ROBOTIC SURGERY: A JOURNEY

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Abstract:

Historically, the natural evolution observed in the operating theatre began with the shaping of surgical instruments used for cutting, holding, and grasping, into articulated master-slave instruments. These new tools have been used either as passive mechanical tools or actively under the control of the surgeon. Minimally Invasive Robotic Surgery (MIRS) makes use of robotic manipulators to alleviate the drawbacks associated with MIS. Improvements offered by MIRS systems include increased precision, better maneuverability and enhanced dexterity. One benefit of robotic surgery is the ability to perform tele-surgery. One of the limitations of using robots for surgery may be about the ergonomic disadvantages; associated with such complex systems and their surgical instruments. This paper deals with developments of robotic systems in all the areas of surgery by removing the limitations of past systems.

Keywords: Master Manipulator, Robotics Surgery, MIS, MIRS and Ergonomic factors

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1. Introduction

The concept of robots as forced labor, derived from the Egyptians, who built water clocks that served as oracles. It has been suggested that 'Leonardo DaVinci' had a mechanical lion that walked and roared. It is in the Karel Capek's play "Rossum's Universal Robots" [Capek, 1921] that the word robot first appears in literature. The robots in this play lead to the destruction and downfall of society. The first major advances in the introduction of modern robots occurred in industry followed the Second World War with the invention of the mechanical robot arm. This new device could emulate the motion of an operator from a distance. Engineers then developed the robot arm into a programmable arm, able to perform a wide range of tasks. General Motors rapidly put its creation into use in 1961 on production lines in the automobile industry. Industry also used robots in heavy lifting, repetitive or boring tasks such as spray-painting and hazardous environments such as nuclear and deep-sea environments. Taylor's definition highlights that a robot cannot only move parts, but can be defined as a programmable machine that can extend human capabilities such as the senses. The development of robots in healthcare may be classified as: (i) Laboratory robots (ii) Rehabilitation robots (iii) Robots in surgery (iv) Robots in MIS

1.1 Robots used in surgery

Over the past15 years, MIS has seen the introduction of powered master-slave instruments in which the surgeon acts as the controller (the master) and initiates the commands, and the robot (slave) responds accordingly with different types of motors. Master-slave robots were developed by incorporating a computer within the device, enabling the user to carry out a task with greater accuracy and precision [Hashizume, 2005 and Ray man, 2005].

Further development of these master-slave robots allowed the transmission of commands from a distance. The surgeon would operate the robot and perform surgical procedures from a distance using high-speed communication systems such as the Internet. A further step in this evolutionary pathway would be the introduction of autonomous robots instructed to perform specific operations independently from the surgeon. Any such development would, however, raise many challenging ethical questions.

1.2 Robots in minimally invasive surgery (MIS)

MIS imposes certain restrictions and challenges over open surgery, the surgeon works through a set of holes approximately 1 cm in diameter. Long handled instruments cut and grip tissue within the body, and a video camera laparoscope provides a view of the internal operating field [Howe, 1999]. Unlike open surgery, MIS avoids long incisions. Studies have also shown that compared with open surgery, MIS patients recover more quickly, have reduced discomfort, improved healing, reduced convalescence and hospitalization costs, and spend less time away from productive work. The dexterity required [Arora, 2005] in MIS is different to that required by open surgery. Having only a few fixed points of entry for the instruments, MIS limits the type of movement, for example, lateral movement is not possible. The fulcrum effect has been widely identified as one of the main challenges of MIS. The fixed entry point pivots the instrument causing a fulcrum effect, resulting in reversed movements of the instruments inside the abdomen, thus making the operation mentally more challenging.

1.3 MINIMALLY INVASIVE ROBOTIC SURGERY (MIRS)

This implies that the surgery is done where the patient and the surgeon are located at different geographical locations. This application was first demonstrated in 2001 when a patient in Strasbourg, France, received a robotic cholecystectomy from the ZEUS robotic system [Larkin, 2008] while the surgeon was located in New York. Additionally, MIRS offer many other advantages over normal MIS. The most significant are the elimination of the fulcrum effect, improved dexterity and removal of the surgeon's hand tremors. The robot's ability to restore proper hand-eye coordination makes it possible for the surgeon to use more natural movements with reduced fatigue. This increases the safety of the patient and also protects the surgeon against unintended mistakes. Most robotic systems achieve these advantages by having a separate surgeon and patient console. The surgeon is able to take up a seated position when performing surgeries while the patient side console can be moved and adjusted to be in the correct position for the required surgery. Even though robotic surgery has all these benefits, the existing systems are extremely expensive. The cost is usually the prohibiting factor when a hospital has to make a decision on whether a MIRS system would be beneficial to them.

1.4 Applications of robotics in surgery

The field of surgery is currently undergoing drastic changes in an effort to provide less invasive solutions for patients. Laparoscopy has been adopted as the gold standard for growing number of procedures. Novel techniques such as SIL (Single Incision Laparoscopy) and NOTES (Natural Orifice Translumenal Endoscopic Surgery) are gaining clinical importance, and applications are growing rapidly. These techniques might provide several advantages over open surgery procedures such as faster recovery, shorter hospitalization, lower postoperative pain, and better cosmetic results.

However, the medical community is increasingly concerned about the ergonomic disadvantages associated with such complex systems and their surgical instruments. Problems range from mental stress to physical discomforts that can a posteriori lead to severe musculoskeletal disorders. According to the Institute of Medicine (IOM), about 1.3 million Americans are seriously injured each year by adverse events involving medical products. Consequently, the US Food and Drug Administration highlight the importance of ergonomics in this field. Some of these ergonomic drawbacks have been overcome with the introduction of tele manipulated robotic surgical systems, composed of two main elements:(1) a patient-side surgical robot (slave) and (2) a console from where the surgeon remotely controls the surgical robot (master console). Surgeons are seated, their forearms rest on pads, and the manipulation is highly simplified when compared with traditional laparoscopic techniques. Recent studies suggest that sources of discomfort are also present in robotic surgical systems, especially neck and back muscle hardening because of the non neutral back position. Because of these above mentioned negative effects of the ergonomics of surgical instrument, the involvement of surgeons in the design process of new surgical instruments is central. It not only helps in the acceptance of the new device but also ensures good surgical performance while guaranteeing the safety of both patients and surgeons. Numerous studies have addressed the ergonomic factors that should be considered while designing a surgical instrument for a specific surgical technique. These and other studies mainly investigated posture, mental workload, pressure distribution, and so on. However, the trend has been reversed, and new surgical techniques have arisen or evolved together with the invention of novel instruments and the possibilities that they bring. The acceptance of a new surgical instrument within the medical community relies on a great number of factors that are not always objective, and thus, it is challenging to assess the min a holistic way.

1.4.1 Ergonomic factors influencing surgeon

This article presents an across surgical-techniques study that attempts to identify the principal factors (background, ergonomics, working conditions, etc) influencing surgical instrument acceptance. A survey was conducted with 250 surgeons with the experience in laparoscopy, and robotic procedures were included in study. Surgeons were asked questions separated into three areas.

(i) Discomfort and procedure duration
(ii) Handle evolution
(iii) Handle preference

1.4.1.1 Discomfort and procedure duration

The first part of questionnaire was related to pain and discomfort suffered during or following surgical procedures. Surgeons gave details of the body parts that suffered any kind of discomfort for each surgical technique. To compare the ergonomic issues associated with open, laparoscopic, and robotic surgery, percentages were calculated for each part of the body [Carrers, 2012] and within the group of surgeons who had experience in each surgical technique. As task duration represents an important risk factor for work related injuries, surgeons provided additional information regarding the average duration of the surgical procedures that they perform. The percentage of surgeons voting for each duration range was calculated for all the surgeons first and then separately for the groups with/without experience in robotic surgery.

1.4.1.2 Handle evaluation

The second part of the survey consisted of the evaluation of different surgical instrument handles. Seven pictures of surgical instrument handles were presented, and the surgeons were asked about the ergonomics and usability of the open–close mechanism of each instrument. Having in mind such an action, surgeons had to score each handle in terms of intuitiveness, [Carrers, 2012] comfort, precision and stability. A supplementary question asked about the addition of extra features and controls on the surgical instrument handle.

1.4.1.3 Handle preference

In the third part of the survey, surgeons could choose their preferred instrument(s) and eventually explain the reasons for their choice. Since one of the goals of the present study is to determine which are the most influential aspects (intuitiveness, comfort, precision, and stability)on the surgeon's preference regarding the surgical instrument handles, an automatic stepwise multiple variable linear regression with a critical value of P = .05 was performed.

1.5 Handel design for robotic surgery

There will always be a need for well-designed hand tools and hand operated controls despite newer technology. Good handle design is important at work and in all kinds of daily activities for items that are efficient to use, safe, and attractive to buy. Anything that can be picked up by the human hand or which the body comes in contact with is in some sense a handle. All these need some of the same features, whether it is a door or a door-handle pushed open by the body, or a book or glass or box, or any of a hundred thousand other items. The author of children's books about Peter Rabbit, Beatrix Potter, insisted her publisher made her books small, to fit the small hands of children, at the same time as the typeface was large to make reading easy. Like many expert and intelligent people she was an excellent intuitive ergonomist. Newer demanding activities such as minimally invasive surgery have put more critical demands on hand-work than in the past. There is an even greater need apply principles of good design to handles and understanding better how they are to be used. There are other reasons for looking at the ergonomics of handle design for products. They are more likely to sell better when competing internationally with established manufacturers. Here we will look at the common types of hand-grip, their features, and how they hold and use items. Most of the article consists of more than 50 criteria against which the design of a handle or hand-held item can be compared, and it includes ways of checking some features of handle design.

The simple act of gripping a hand-rail to support the body can suggest the desirable thickness, length, and position of a general purpose handle, and perhaps some other criteria as well. However, individuals vary in how they grip according to their habit and size, and the same individual may vary the grip according to posture, force needed, other constraints, or for no obvious reason at all. The problem of allowing for different grips can be solved by tailoring handles to different users and situations. This makes it even more important to have a general list of factors for handle design, which can be applied to different types of work and other activities. It is necessary to begin by looking at ways in which humans grip handles. The two main ways are the power grip, for large heavy items, and the pinch grip, for small light items. Variations of these two make it worth considering six common basic grips which are as follows:

(i) Power grip (ii) Pinch grip (iii) External precision grip (iv) Internal precision grip (v) Ulnar storage grip and (vi) Other grips

1.5.1 Criteria for handle design

Following factors are important in the design of handle of robot:

(i) Size (ii) Shape (iii) Surface (iv) Security (v) Stiffness (vi) Surrounding (vii) Special other features (viii) Sensing features

(i) Size

Length should be at least 10 to 15 centimeters so as to fit the width of palm and should be longer for long handed population. Thickness should be such that thumb just covers the end of index and middle fingers. For maximum power in adult male, it should be 3 or 4 centimeters in diameter, Figure 1 shows hand diameter specifications.

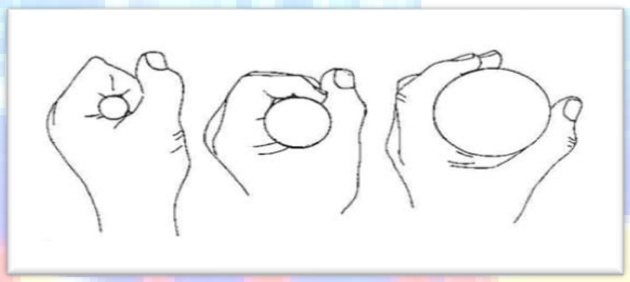

Figure 1 Handle diameter specifications

(ii) Shape

Uniform diameter and smooth surface along the length, thickened centrally if there is need to secure against sliding. It should be flattered for thumb and fingers to prevent unwanted twisting, no sharp edges or high spot in area of grip because this decreases comfort, strength and security of grip .However an edge or raised area is useful on the end of non grip area of handle.

(iii) Surface

A smooth surface is better if it is non-reflective, to avoid glare in brightly-lit work. This is common problem with surgical instruments. Insulation against heat, vibration, electricity should be provided.

(iv) Security

Against slip should be provided to the handle with gentle finger grooving. Non rounded to stop a handle rolling off a sloping work surface.

(v) Stiffness

The force needed to use handle occasionally should be less than one third of average possible maximum for user population. Standard handbook of ergonomics or human factor should be used.

(vi) Surroundings

Adequate clearance around the handle for access, avoiding finger damage on aperture edge, awkward posture, and obstructed line of vision.

(vii) Special other features

Handle should be easy to maintain. Replacement for wear and tear, special user such as left handers, disabled. Add on-For extra leverage, or thick gloves, or four handed use.

(viii) Sensing features

Effect of using the control should be visible or audible to user. The effect of use may be indicated by special signal device

1.5.2 THE ERGONOMIC FACTORS

Following factors are important in ergonomic design:

(i) Stretch ((ii) Speed (iii) Strength (iv) Susceptibility

Although technology has developed other interfaces with humans, through voice, eye-movement, and even electroencephalography (EEG or brain-waves), the human hand will be a dominant feature of humans for millennia to come. Accordingly, careful design of handles will be important and worth-while [Patkin, 2001], especially for demanding activities. A check-list will need to be updated every two years or so, in accordance with new experience, Information and new challenges.

1.5.3 Performance specifications for master manipulator

Following parameters are important to decide the performance of master manipulator.

(i) Working area of the micro processing
(ii) Design of workspace and mechanism
(iii) Correspondence of Translational

(iv) Gripping Action of Master Manipulator

A general outline of the system is shown in Figures 2. This system consists of 3 parts which are

(i) Master manipulator,

(ii) Control system

(iii) Slave manipulator or surgical tool

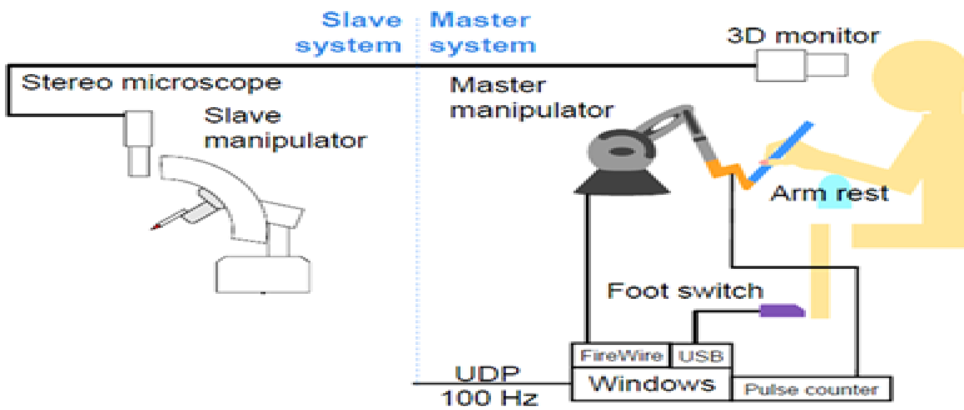

Figure 2 sample master manipulator with operator

1.6 Master slave robotic system for MIRS

In some cases larger operating rooms are required to accommodate these systems since they take up a lot of space. Another potential problem is the upgrading of a system. Hospitals are concerned about how much it would cost to upgrade and how often they would need to do it. Many also believe that the purchase of a robotic system would be adopted more easily if the system had a more widespread multidisciplinary usability. Consequently, an inexpensive MIRS system can offer a competitive edge. Such a system can be used to perform the procedures that are less complex and done more frequently [Hang, 2010]. Complex procedures can then be referred to the more sophisticated robotic systems or can be done manually. The less expensive system will be more accessible to most medical centers, which can improve the delivery of healthcare to all patients.Many of the current developments of technologies related to robot-assisted MIS are based on the DaVinci surgical system [Lanfranco, 2004].

The system typically consists of the surgeon's console, the surgical arm cart and high resolution 3D imaging system. This also highlights another advantage of robotic surgery: the possibility of remote surgery ortelesurgery, which enables the surgeon to be fully removed from the site of surgery.

Advanced Robotics and Mechanism Applications Research Laboratory of Columbia University are developing a tele-robotic system for MIS of the throat and upper airways [Simaan, 2009]. They used the DaVinci master interface as their master workstation and designed a dual-arm robotic slave manipulator with a novel flexible snake-like end-effector. They believe that this snake-like end-effector can provide the surgeon with more dexterity inside of the throat. University of Hawaii-Manoa also have developed a compact, less intrusive, teleoperated robotic minimally invasive surgery system [Berkelman, 2006]. Figure 3 shows the surgeon seated at the console on the left while the surgical arm cart is busy in operating of a patient on the right. Figure 4 displays the slave manipulator while Fig. 5 shows the Master console. The movement of the surgical tool is fully controlled by the surgeon at the operator's console. This console, with its ergonomic design provides a comfortable position for the surgeon during a surgical operation, which helps to keep the surgeon's position steady and therefore minimizes human error due to fatigue. While sitting at the console, the surgeon can observe the 3D, real time video image (often magnified up to 10-15 times) as if looking down on the physical operative site.

Figure 3 Master, slave and control system

Figure 4 Slave manipulator

Figure 5 Master console

2. LITERATURE REVIEW

The work of various researchers in this area is summarized in this section.

Kawai (1986) worked on master manipulator. When an operator moves the grip member in the first bending direction x or in the second bending direction y or in the third twisting direction z, the three motions are detected by three sensing means independently to drive a slave manipulator in the same way. The master manipulator comprises four members of a first lever pivotable around the axis X, a second lever pivotable around the axis Y, a connecting member, and a link member, which forms a transformable parallelogram with three universal joints as joints. To detect only the third twisting motion z, the above mechanism may be sufficient. However, to detect other two bending motions x and y simultaneously, the master manipulator is further provided with a bending motion transform assembly and a spherical bearing assembly. In the bending motions x and y, a parallelogram is formed, in particular, with the spherical bearing disposed near the third universal joint as joint, and the two motions x and y of the link member are detected by way of the transform assembly. Hida (1990) developed apparatus for controlling a manipulator which employs a control device, first to third detectors, a producing device and a driving device. The first detector detects an operating force/torque generated by the control device and the second detector detects a deflecting amount of the control device from a reference position. The third detector detects an end force applied on an end portion of the manipulator and reaction signals are generated by the producing device. The reaction signal corresponds to a function of the deflecting amount and the end force. A force/torque corresponding to the difference between output signals from the first detector and the producing device are generated by the driving device and applied on the control device

Akoi (1992) developed a master slave manipulator system which includes a master arm having six or more axes of motion and an articulated slave arm having six or more axes of motion and being shaped in sharp contrast with the master arm. The master arm has an arm body with three axes perpendicular to each other and a wrist assembly connected to the arm body. The wrist assembly has a gripper disposed in a space of a size large enough for an operator to operate the gripper with his clutched hand in X, Y and Z directions and also has a pitch-axis, a yaw-axis and a roll-axis all disposed outside of the space. The pitch-axis, yaw-axis and roll-axis have output axes directed toward the gripper. The slave arm has an arm body with axes longitudinally stretchable or foldable into parallel positions, and a wrist assembly having three axes disposed in a space of predetermined dimensions in X, Y and Z directions. The output axes of the three axes of the slave arm wrist assembly are directed away from the mounting portions of these axes. The slave arm is so controlled as to follow movements of the master arm. Horii (1997) presented a surgical manipulator system. He developed a surgical manipulator system comprising at least one surgical manipulator, one guide, a detector, and a drive controller. The surgical manipulator has surgical device for performing a desired operation. The guide guides the surgical device; the detector detects a position and orientation relationship between the surgical device and guide. The derive controller controls the surgical manipulator such that a surgical device is guided by the guide. They have developed the master manipulator with five links arrangement. This master manipulator has specific base coordinate system. Each base coordinate system is an orthogonal one, having an origin at base and three axes x_0, $y_{0,}$ $z_{0.}$ The controller for both master manipulators sets the position and orientation of master manipulator with respect to specific coordinate system. There is actuator on each master manipulator system and it generates the force which acts against the force the surgeon is applying on master manipulator. As the surgeon operates the master manipulator the slave manipulator which is associated with master manipulator is operated in same way. Kenji (1999) worked on master slave manipulator and control methods. The present invention relates to a master /slave manipulator and a method for controlling the same, in which a large working area and good controllability can be provided and a corresponding position shift and an enlargement ratio change can also be attained. To this end, a plurality of representing points are set on and inside a closed surface of an operating area of one manipulator, while a plurality of target points corresponding to the plurality of representing points are set on and inside a closed surface of a working area of the other manipulator. Working amounts when the leading ends of the one manipulator and the other manipulator respectively reach the plurality of representing points and the plurality of target points, and a corresponding relationship between the working amounts of the two manipulators are obtained; and when the slave is to be operated, the working amounts of the master are converted into working amounts of the slave to thereby operate the slave.

Jacobus (2000) used a force feedback system. A method for controlling force feedback in a force feedback system using a computer mediated control system, said force feedback system including at least one actuator and at least one position sensor. This design will give us a system and method for providing a tactile virtual reality to a user is present. The position and orientation of the user is utilized to generate a virtual reality force field. Forces are in turn generated on the user as a function of this force field. A six-axis manipulator is presented for providing a user interface to such a system. This manipulator provides a unique kinematic structure with two constant force springs which provide gravity compensation so that the manipulator effectively floats. Somerville (2000) developed handles of a user interface for various applications, including minimally invasive surgery (MIS). A modified MIS tool handle has two shafts that translate relative to each other upon relative motion of the handles. They also can rotate relative to each other. The first is translationally fixed and rotatably free relative to the housing. An actuator actuates rotation of the first shaft. The second shaft is coupled to the housing such that it is rotationally fixed about and translatable along the axis of its elongation. The second shaft is fixed to a cartridge that is a linear capstan and translates relative to the housing, in response to relative translation of the shafts. A jaw action actuator is coupled to the cartridge through a cable drive, and can actuate the relative translation of the shafts, and thus, the handles. The jaw action actuator can actuate jaw action of a tool in a tool environment, either virtual, or actual. The first actuator can actuate rotation of the tool in a tool environment. The handle module can actuate both the jaw action of a jawed tool, as well as rotation around the long axis of the shafts. The actuation may also provide force feedback, for use as a simulator, or telerobotic master. A base mechanical interface can be added, that provides additional degrees of freedom, to enable simulation and force feedback that represent MIS insertion, pitch and yaw around the insertion point. Nakamura et al. (2001) developed the multi-DOF forceps manipulator with two additional DOF of bending on the tip of forceps, and provides new surgical fields and techniques for surgeons. The most remarkable characteristics of their prototype are: (i) the small diameter and the small radius of curvature of bending; and (ii) the confirmation of perfect cleanness and sterilization of this manipulator.

Shimaru (2003) designed a medical instrument holding apparatus. A medical instrument holding apparatus comprises a support arm supported such that it is rotatable about a first axis of rotation, a first arm supported such that it is rotatable about a second axis of rotation, a second arm supported such that it is rotatable about a third axis of rotation, and a third arm supported such that it is rotatable about a fourth axis of rotation. This apparatus further comprises first, second, third and fourth locks for locking the support arm, the first arm, the second arm and the third arm about the first, second, third and fourth axes of rotation, respectively, and for releasing the locked states of the arms. This apparatus can select control for causing predetermined three of the first, second, third and fourth locks to execute a locking operation, or control for causing all the locks to execute the locking operation.

Tadakuma et al. (2005) developed a robotic arm for a master-slave system to support "mutual telexistence," which realizes remote dexterous manipulation tasks and close physical communication with other people using gestures. They described the specifications of the experimental setup of the master-slave arm to demonstrate the feasibility of the mutual telexistence concept. The master arm of a telexistence robot for interpersonal communication was developed. The last degree of the 7-degree-of-freedom slave arm is resolved by placing a small orientation sensor on the operator's arm. This master arm was made light and impedance control is applied in order to grant the operator as much freedom of movement as possible. They compared and confirmed three control methods found that the impedance control method is the most appropriate to this system. Shin et al. (2006) presented a surgical manipulator system with 5 DOF laparoscopic assistant robot system which takes into account a number of requirements for assisting with laparoscopic surgery. The proposed system is expected to allow various laparoscopic surgeries to be performed with minimal interference with the surgeon. System analysis and experimental results of the system performance are presented. Steve Jordan (2006) suggested method and apparatus for robotic surgery. A robotic system that moves a surgical instrument in response to the actuation of a foot pedal that can be operated by the foot of a surgeon. The robotic system has an end effector that is adapted to hold a surgical instrument such as an endoscope. The end effector is coupled to a robotic arm assembly which can move the endoscope relative to the patient. The system includes a computer which controls the movement of the robotic arm in response to input signals received from the foot pedal.

Ghodoussi (2006) developed a robotic arm that is attached to operating table. A system for performing minimally invasive cardiac procedures includes a pair of surgical instruments coupled to a pair of robotic arms with end effectors that can be manipulated to hold and suture tissue. The robotic arms are coupled to a pair of master handles by a controller to produce a corresponding movement of the end effectors. The movement of the handles is scaled such that the end effectors movement corresponds differently, typically smaller, than the movement performed by the hands of the surgeon. The input button allows the surgeon to adjust the position of the handles without moving the end effector, so that the handles can be moved to a more comfortable position. The system may include a robotically controlled endoscope allowing the surgeon to remotely view a surgical site. The surgeon may manipulate handles and move end effectors to perform a cardiac procedure. Rodomista (2006) developed a force reflecting haptic device. Force reflecting haptic interfaces and associated computer hardware and software are used in a variety of systems to provide tactile sensory feedback to a user in addition to conventional visual feedback, thereby affording an enhanced man/machine interface. These systems are becoming more prevalent in such diverse areas as surgical technique training, industrial design and modeling, and personal entertainment. In this design a six degree of freedom force reflecting haptic interface includes three powered axes and three free axes was developed, all of which are tracked so that the position of a user connection element in the work volume can be determined. The interface includes cable drives with polymer composite or metallic cables, automatic cable tensioning devices, and grounded actuator capstans. A nested hub and transfer drive provide a compact, weight balanced interface. User comfort and safety features are also provided.

Ghodoussi (2008) suggested the MIS training using robotics. Before surgeries has been performed by making large incisions in a patient to provide access to the surgical site. There has been developed instruments that allow a surgeon to perform a procedure through small incisions in the patient. The instruments include an endoscope which has a camera that allows the surgeon to view the internal organs of the patient through a small incision. This study gives us an idea about medical system that allows a mentor to teach a pupil how to use a robotically controlled medical instrument. The system may include a first handle that can be controlled by a mentor to move the medical instrument. The system may further have a second handle that can be moved by a pupil to control the same instrument. Deviations between movement of the handles by the mentor and the pupil can be provided as force feedback to the pupil and mentor handles. The force feedback pushes the pupil's hand to correspond with the mentor's handle movement. The force feedback will also push the mentor's hand to provide information to the mentor on pupil's movements. The mentor is thus able to guide the pupil's hands through force feedback of the pupil handles to teach the pupil how to use the system.

Ruizmorales (2010) developed medical robotic system for performing medical procedures comprises a robot manipulator for robotically assisted handling of a medical instrument, in particular a laparoscopic surgery instrument. The robot manipulator comprises a base, a manipulator arm with an essentially vertical part supported by the base and with an essentially horizontal part supported by the vertical part, a manipulator wrist supported by the manipulator arm, and an effector unit supported by the manipulator wrist and configured for holding a medical instrument. The manipulator arm has a cylindrical PRP kinematic configuration for positioning the manipulator wrist. More particularly, the PRP kinematic configuration has the following joint sequence: a prismatic (P) first joint (J**1**) for varying the height of the vertical part by providing a translational degree of freedom along an essentially vertical axis, a revolute (R) second joint for varying the rotational angle between the vertical part and the horizontal part by providing a rotational degree of freedom about an essentially vertical axis, and a prismatic (P) third joint (J3) for varying the reach of the horizontal part by providing a translational degree of freedom along an essentially horizontal axis. Dan Sanchez (2011) developed a multifunctional handle for medical robotic system. A handle used to control movement of a medical instrument. The medical instrument may be coupled to a robotic arm that is connected to a controller. The medical instrument may have a plurality of functions such as wrist locking and motion scaling. One of the functions may be selected through a graphical user interface operated by the end user. The handle may have a plurality of buttons. One of the buttons may allow the end user to control the selected function. For example, when wrist locking/unlocking is selected, depressing the button can toggle the medical instrument wrist between a locked state and an unlocked state.

Katsuki (2012) developed a medical manipulator system that has an operating unit including a grip handle and a composite input unit, a working unit detachably mounted on the operating unit and including an end effector, and a controller for controlling the operating unit. The controller judges starting and ending of a surgical case and increments the usage count of the working unit based on a manner in which the working unit is mounted and dismounted, and the times at which the working unit is mounted and dismounted, and disables the working unit if the usage count of the working unit exceeds a preset count. Tususaka (2012) suggested a control apparatus for a master -slave robot includes a force correction section detecting unit that detects a section at which force information from at least one of force information and speed information is corrected, and a force correcting unit that corrects the force information at a section detected as a force correction section by the force correction section detecting unit. A small external force applied to a slave manipulator is magnified and transmitted to a master manipulator, or an excessive manipulation force applied to the master manipulator is reduced and transmitted to the slave manipulator. Ryohei (2012) developed a master manipulator for operating driving of a slave manipulator includes a grip portion that is positioned in a clean area, gripped by an operator, and provided with a predetermined operating member and an arm portion that is positioned in an unclean area, and with which the grip portion is directly or indirectly connected. The grip portion has a movable member that moves in conjunction with displacement of the operating member and the arm portion has a position detection portion that detects the position of the movable member. Kamei et al. (2012) designed the master manipulators for master-slave surgical robotic systems. However, no design strategy has been presented for optimizing the master manipulator design parameters. A master manipulator prototype and an experimental setup were developed for investigating design parameter influence using our master-slave microsurgical robotic system. The preliminary results show that the relative position of the holding point, the corresponding point for the slave manipulator's working point, and the center of the gimbals are important for master manipulator design, especially for tasks requiring large or frequent posture changes. The experimental results also suggested that the optimized parameters would contribute to enhancing task efficiency and decreasing the workload, rather than increasing task accuracy. Orsino and Coelho (2013) suggested parallel kinematic structures with adequate architectures for positioning and orienting the tools of robotic mechanisms. However, developing dynamic models for this kind of systems is sometimes a difficult task. They stated that the direct application of traditional methods of robotics, for modeling and analyzing such systems, usually does not lead to efficient and systematic algorithms. They addressed this issue and presented a modular approach to generate the dynamic model through some convenient modifications. They used Kane's formulation to obtain the dynamic equations to deal with redundant coordinates and kinematic constraints, so that a suitable choice of a set of coordinates allows the remaining of the modeling procedure to be computer aided.

Salimi et al. (2014) developed robotic system to assist with sophisticated medical interventions such as aortic valve replacement under beating heart conditions necessitates the development of dexterous manipulators to ensure a safe and reliable operation. They claimed that these mechanisms should not only be capable of tracking the desired trajectories with a high level of accuracy but also need to cope with strict medical constraints such as environment compatibility, patient safety and compactness. They proposed a robotic platform that takes into account the aforementioned requirements. In addition to the detailed description of the robot design and its dedicated power transmission system, they also presented the derivation of the robot's forward and inverse kinematic equations. Jawale and Thorat (2014) designed open chain and closed chain manipulators for specific objectives. They presented comparative analysis of positional inaccuracy of closed chain five bar manipulator and serial chain configuration. Both manipulators were modeled for positional deviations under identical specifications considering randomness due to joint clearances and backlash in drive. They expressed maximum positional inaccuracy in terms of dimensionless number as error index (EI) to estimate the comparative behavior of the manipulators. Positional error under influence of backlash and clearances is quantified. Comparison of two configurations is presented and conditional superiority of a configuration over the other is commented using geometric approach. Li-xin and Yong-gang (2014) investigated the effects of joint clearance on the dynamic performance of a planar 2-DOF pick-and-place parallel manipulator. The parallel manipulator is modeled by multi-body system dynamics. The contact effect in revolute joints with clearance was established by using a continuous analysis approach that is combined with a contact force model considering hysteretic damping. The evaluation of the contact force is based on Hertzian contact theory that accounts for the geometrical and material properties of the contacting bodies. By numerical simulation, variations of the clearance joint's eccentric trajectory, the joint reaction force, the input torque, the acceleration, and trajectory of the end-effector were used to illustrate the dynamic behavior of the mechanism when multiple clearance revolute joints are considered. Their results indicate that the clearance joints present two obvious separation leaps in a complete pick-and-place working cycle of the parallel manipulator, following a collision. Finally, they proposed related approaches to decrease the effect of joint clearances on the system's dynamic properties for such parallel manipulator and prevent “separation-leap-impact” events in clearance joints.

3. CONCLUSIONS

This paper presents the development and applications of robotic systems in the various types of surgery. By using this design, a surgeon can hold the grip portion of master manipulator while performing the surgery by looking at the 3D display. As the robotic surgery requires high precision and for better surgery the master manipulator should have all the features which may enhance surgeon dexterity. Master manipulator design for master slave surgical robot is important because it influence the slave manipulator performance. Master manipulator designed in this paper requires encoders to be mounted at every joint, so that hand movement of surgeon should be picked by encoders, scaled down and then transferred to slave manipulator.

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