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SURVEY ON FORCE SIGNAL CONTROLLING FOR ROBOTIC ARM AND ROBOTIC ARM USING IN SURGERY

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ABSTRACT

The robotic assisted surgery has emerged with the pledge of extending the benefits of minimally invasive surgery to almost every surgical specialty while decreasing patient morbidity and improving post working outcomes. This article reviews the history, development, current applications of robotics in surgery, and various controlling method of surgical Robotic arm are investigated.

Keywords: *Surgical robotic, force balance concept, force signal tuning, PID controller, fuzzy logic, artificial neural network, genetic algorithm..*

I. INTRODUCTION

The name 'robot,' derived from the Czechoslovakian word robot *a* meaning 'forced labor', was made popular by the playwright Karel Capek in his 1921 play *Rossum's Universal Robots* about autonomous human-like devices that were created to perform common tasks[1]. Robotic Institute of America as defined For the next half-century, the robots, "reprogrammable multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a multiplicity of tasks" did just that, as they handled risky works, and performed repetitive tasks (auto industry) or assembled parts (computer chips) with great accuracy. These devices have been categorized into active, semi-active, or passive (master-slave) systems. Active systems perform a task separately requiring only the supervision of a surgeon while passive systems possess no independence and require a surgeon's input entirely. The first robotic-assisted surgery was performed by Kwoh in 1985[2]. He modified a standard industrial robot to hold a fixture next to a patient's head, so drills and biopsy needles could be inserted at a desired location for neurosurgery.

While Erich Muhe, MD performed the first laparoscopic cholecystectomy in 1985[6], surgeons have continued to search for ways to implement minimally invasive techniques within all specialties. Due to the need for superior idea or complex reconstruction, many of these procedures were simply not feasible using standard laparoscopic techniques or instrumentation. The emergence of computer-assisted and robotic technology has permitted surgeons, once again, to achieve that end by augmenting their abilities, often beyond what is humanly possible. This object highlights these technologies by reviewing the history, development, current and future applications of robotics in surgery.

Named the 'Probot,' this marked the first time that an active robot was used to automatically remove soft tissue from a patient. Near the same time, Taylor et al. developed the ROBODOC (Integrated Surgical Systems, Sacramento, CA) as an industrial arm that would accurately core out the femur for stylish replacements. This marked the first commercially available surgical robotic system. Regardless of a large clinical trial representing that the system produced radio graphically superior fits for implants while eliminating femoral fractures, the device was associated with greater blood loss and operative times and has not yet achieved Food and Drug Administration (FDA) approval in the United States. Extra work in robotics was taking place simultaneously with collaboration between Scott Fisher, PhD at the National Aeronautics and Space Administration (NASA) Ames Research Center (Palo Alto, CA) and Joseph Rosen MD, a plastic surgeon at Stanford University [3]. Both envisioned 'telepresence surgery' by integrating interactive virtual reality with surgical robotics. This was presented to roboticist Phil Green, PhD and his team at Stanford Research Institute (SRI) to develop a telemanipulator for enhancing nerve and vascular anatomies in hand surgery. Recognizing the impact such a system could have on macroscopic endoscopic surgery, Richard Satava, MD, a general Surgeon collaborated with researchers with funding from the U.S. Army to aid in developing the Green Telepresence System [4]. This system was envisioned to decrease mortality in war by "bringing the surgeon to the wounded soldier through telepresence." A wounded soldier would be placed in a vehicle with robotic equipment and operated on by a surgeon located remotely at a Mobile Advanced Surgical Hospital (MASH). This was successfully implemented with an animal model but never for battlefield Also with initial funding from the U.S. Army, Yulun Wang, PhD developed a table mounted robotic arm controlled by the operating surgeon to manipulate an endoscopic camera, the AESOP (Automated Endoscopic System for Optimal Positioning), and formed his own company (Computer Motion, Inc.). This device eliminated the need for a camera holding assistant and, in 1993, became the first surgical robotic device to gain FDA approval, thus ushering in the age of robotics in surgery. While the AESOP was enjoying an early success, the SRI Green Telepresence System was licensed by Intuitive Surgical, (Sunnyvale, CA), extensively redesigned, and reintroduced as the da Vinci Surgical System. In March 1997[5], Cardiere et al. performed the first robotic assisted laparoscopic cholecystectomy in Belgium using this platform. Shortly thereafter, Computer Motion, Inc. produced a competing telemanipulating platform, Zeus. This consisted of the AESOP system with 2 additional table mounted robotic arms controlled by a surgical workstation. In the Zeus system, the surgeon was seated upright in a chair with a 2-dimensional video monitor and instrument handles positioned ergonomically to maximize dexterity.

II. PRESENT ROBOTIC OVERVIEW

As the only commercially available telerobotic system in the world, use of the da Vinci Surgical System (Intuitive Surgical) has exploded since first obtaining FDA approval for general surgical procedures in July 2000. Over 460 systems are currently installed worldwide; over 350 are in the United States. As a purely passive, or 'masterslave' system, most roboticists would agree that the platform is not really a robot at all, but merely computer-assisted surgery at best [7]. The platform consists of 3 main components: an ergonomic surgeon console, a vision cart holding a dual light source and dual 3-chip cameras, and a movable surgical cart which contains 2 or 3 mounted arms and a camera arm. The master console consists of an image processing center generating a magnified 3-dimensional image in the View port, foot pedals to control the electrocautery, camera and instruments, and master control grips that drive the robotic arms at
the patient's side. The surgery is greatly facilitated as the surgeon's hand-eye axis is positioned to give the false impression of directly operating on the patient through an open cut while he or she is seated comfortably at the console (See Figure 1).

Figure 1 Master control Surgery by Robotic arm

The articulating laparoscopic instruments (Endo Wrist) have complex cable driven joints at the distal end allowing the same seven degrees of freedom (in/out, axis rotation, up/down [pitch], left/right [yaw], grip, and pitch and yaw at the wrist) present in the human hand during open surgery (See Figure 2).

Figure 2 open surgery

Later in its development, 3 dimensional viewing became available. In March of 2003, the two opposite companies merged and production of the Zeus system was discontinued [8]. In the last seven years, Intuitive Surgical, currently the only commercial manufacturer of a telerobotic system in the world, has made only modest improvements (slightly smaller size, arms with increased range of motion for cross specialty use, and the potential for integrated imaging) in its latest system (da Vinci Sa introduced in January 2006) with no decrease in cost[9]. Weinstein, O'Malley, Snyder, Sherman and Quon (2007) introduced the new technique of transoral robotic surgery (TORS) radical tonsillectomy which gave more view of transoral region for surgeon to operate tonsillar carcinoma through robotic instrumentation without the replacement of tracheotomy tube and open surgery [10]. In India the first robotic urology surgery was performed in April, 2005 and first robotic thoracic surgery (thoracoscopic thymectomy) in 2008. Recently, CARE Foundation in collaboration with Indian Institute of Information Technology (IIIT) Hyderabad has undertaken the task of developing indigenous robotic surgical systems. With installations in the United States, Europe and Japan, the system has been used in 8000 stereotactic brain surgeries by 2009. In September 2010, the first robotic operations with Hansen Medical's Magellan Robotic System at the femoral vasculature were performed at the University Medical Centre Ljubljana (UMC Ljubljana), Slovenia. The research was led by Borut Geršak, the head of the Department of Cardiovascular Surgery at the centre. Gersak explained that the robot used was the first true robot in the history of robotic surgery, meaning the user interface was not resembling surgical instruments and the robot was not simply imitating the movement of human hands but was guided by pressing buttons, just like one would play a video game. The robot was imported to Slovenia from the United States. Between June 2011 and September 2012, over 150 neurosurgical procedures at the MNI/H have been completed robotized stereotaxy, including in the placement of depth electrodes in the treatment of epilepsy, selective resections, and stereotaxic biopsies. Stanmore received FDA clearance in February 2013 for US surgeries but sold the Sculptor to Mako Surgical in June 2013 to resolve a patent infringement lawsuit.

III. CONTROLLING METHOD OF SURGICAL ROBOTIC

The Controlling methods of surgical Robotic arm are investigated. First The PID Controller is most popular for controlling robotic arm, but this method require more time for desired response because the gain of PID parameters such as K_p, Ki and K_d value are selected by hit and trial method. Second popular method is fuzzy Controller, this method require writing rule according to desired output response of system. But this method require more time for Controlling, because written rules are changing according to desired output. Third method is artificial neural network, this method possess large number of highly interconnected processing elements called neurons. Each neuron is connected with the other by a connection link. Each links requires calculating weight according information about the input signal. But this information used by the neuron net to solve a particular problem which is also require more time for Controlling. Fourth Optimization method like as genetic algorithm and PSO, this method less time require for controlling and better output response
from other method. And author works in controlling for surgical robotic arm some works are explain her.

IV. FORCE SIGNAL TUNING FOR A SURGICAL ROBOTIC ARM USING PID CONTROLLER(2012)

Gamal I. Selim, Noha H. El- Amary, and Dina M. Aboul Dahab**:** In this paper, the modeling, control and simulation of a robotic arm are presented. The aim of the controller is to improve and adjust the output force of the arm using Proportional Integral Differential (PID) controllers. Recently the application of robotics in the field of surgery has open fields of research that has helped make sure the accuracy, desired response output. The system is simulated to consist of the equations of the dynamic motion of the robotic arm with the controller contribution. Using the concept of force balance between the surgical robotic arm and the organ, PID controllers are added to smoothen and to unhurry down the output impact force of the robot in all dimensions. The system is investigated without any control system, with PI controller and PID controller. Different gain values for PID controllers are studied. Output obtained from the simulation show satisfactory response.
A developed control system is designed to control the output force signal of the robotic arm. The control system depends on the force balance concept between the organ and the robotic arm. The system response is evaluated before and after inserting the controller. The controller design is evaluated using a PID controller and the results are investigated. A general representation for the whole system of the robotic arm with its controller is shown in figure No. 3. The input per unit predetermined force signal from the organ (reference signal) and the output feedback signal of the forces are marked.

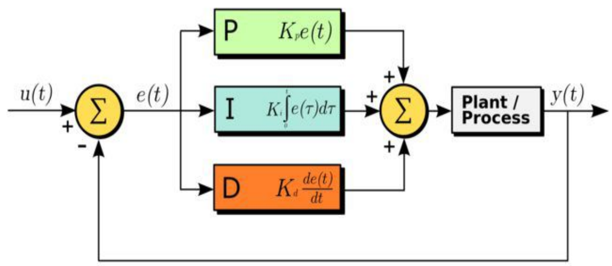

Figure 3 Close loop Control System of the robotic arm

After simulating the studied system on the simulink, the output force results of the system is clarified as follows. The responses of the output force without controller are unstable and with PID controller have stable output but some oscillation and max. Overshoot is present [11].

V. DESIGN OF OPTIMAL PID CONTROLLER FOR INVERTED PENDULUM USING GENETIC ALGORITHM (2012)

MahbubehMoghaddas, Mohamad RezaDastranj, Nemat Changizi, and Narges Khoori: this paper represents controlling of inverted pendulum by using genetic algorithm. In Robotics The stability is a most important problem. If we want to improve stability then controls the robots, in this paper inverted pendulum in robots, first derive nonlinear equation and made simulink model then implements to controller. Controlling Without genetic algorithm only Control By PID controllers take more time for controlling because Parameters adjustment value by hit and trial method. So using the genetic algorithm, this controller tried to optimize, PID controller parameter by using genetic algorithm. Give The output response of the systems is optimum and desired value and reduced time of getting Output response [12].

VI. POSITION CONTROL OF ROBOT ARM USING GENETIC ALGORITHM BASED PID CONTROLLER (2013)

Majed D. Youns1, Salih M. Attya2, Abdulla I. Abdulla3**:** the PID controller is used in every feature of industrial automation. The application of PID controller is high technology industry. The goal of this paper is to design a position controller of a robot arm by selection of a PID parameters using genetic algorithm. The model of a robot arm is considered a third order system. And compare 2-DOF robots of tuning methods of parameter for PID controller. One is the controller design by the genetic algorithm, second is the controller design by the Ziegler and Nichols method. It was found that the proposed PID parameters adjustment by the genetic algorithm is better than the Ziegler & Nichols' method. This method indicates the improvement of the GA-PID controller response. One can easily notice that the improvements are achieved for the three selected fitness function. This variety of fitness functions gives a wide range of selectivity to the designer to choose the appropriate controller parameters that meets desired requirements. The step responses under PID controller tuned by GA for three fitness functions are faster than that response under PID controller tuned by Ziegler –Nichols .However, the ZN method is good for giving the designer the initial guess for the PID tuning.

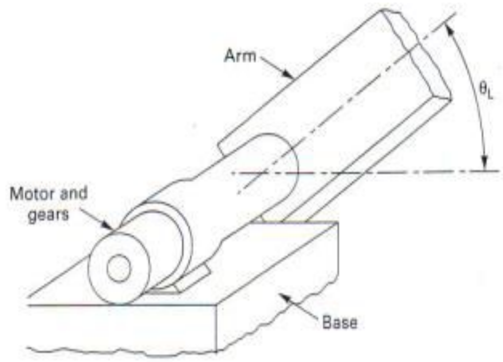

Figure 4 2-DOF robot manupleter

The step response under PID controller tuned by GA is better in terms of minimizing the max overshoot, the rise time and the settling time .Finally the mean square error associated with GA-PID controller is less than the error associated with conventional approach [13].

VII. APPLICATIONS OF ROBOTIC SURGERY

The various applications of surgical robots some current application is:

Cardiac Surgery
The initial commercial telepresence systems were designed for applications within cardiac surgery, specifically coronary artery bypass grafting in a closed chest system.

Urology
Robotic technology has been applied to many established laparoscopic urologic procedures. Utilizing robotic assistance for extirpative procedures such as nephrectomy and adrenalectomy is feasible.

VIII. ADVANTAGES

Surgical robotic platforms like the da Vinci offer many advantages as they overcome several of the obstacles inherent in laparoscopic surgery by providing improved visualization, increased deftness, restored proper hand-eye coordination, and an ergonomic position. With the binocular vision provided by the optical system, the surgeons can regain the depth perception they forfeited with conventional laparoscopy. Additionally, the system offers 6 to 12 times enlargement (depending on the distance from the tissue), thus providing views that allow meticulous dissection to be performed. Since the camera is controlled by the surgeon, he or she can maintain an always stable, optimal view of the surgical field without concern for camera-driver weakness.

IX. DISADVANTAGES

The articulating laparoscopic instruments (Endo Wrist) have complex cable driven joints at the distal end allowing the same seven degrees of freedom (in/out, axis rotation, up/down [pitch], left/right [yaw], grip, and pitch and yaw at the wrist) present in the human hand during open surgery and maintaining this new technology can be high-priced. With the older 3 arm da Vinci Surgical Systems costing just under 1 million dollars, additional costs include a yearly service contract cost of the proprietary instruments, which currently have a limited number of uses before requiring replacement. Additionally, they require a strong commitment not only by the operating surgeon, but by the entire hospital staff as the devices require additional training and experienced personnel. Another disadvantage of the system is its large size. The floor based surgical cart is heavy and the robotic arms can be cumbersome and often limit table side access to the patient.

X. CONCLUSIONS

Though in its early life, robotic assisted surgery is rapidly evolving. This technology appears to offer the greatest advantages in procedures requiring complex reconstruction or dissection as it allows surgeons skilled in open surgery to provide their patients with the known benefits of laparoscopy (decreased pain and more rapid convalescence). At present, these advantages continue to be countered by cost and the need of long term results from

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prospective randomized trials evaluating its efficacy and safety. And the Controlling methods of surgical robots have great importance and direct effects the performance of robots in any works. From the review it is concluded that objective parameters are those parameters which can provide all the necessary information of the surgical robots related to controlling. But this method require more time for desired response because the gain of PID controller are select by hid and trial method. On the basis of which the best controller suitable for a particular works and location may be selected. Our propose work will be for the force signal controlling, three degree freedom surgical robotic arm by using PID controller with genetic algorithm compensated the hit and trial method and directly give optimize value of PID parameters such as K_p, K_i and K_d. The proposed scheme reduces the number of oscillations, maximum overshoot, rise time and settling time as compare to UN-optimize PID controller.

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