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Future Prospects of Artificial Intelligence in Robotics Software, A healthcare Perspective

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Objective: To review the history, development, and current application of intelligent robots in surgical procedures.

Background: In recent years, Intelligent robots have shown promising results in surgical procedures. Surgery conducted by intelligent robots is often heralded as the new revolution and it is one of the challenging aspects of modern surgery. Until now, the enthusiasm to develop intelligent surgical robots has been largely driven by the area of surgery. Intelligent robots are proven to be an important tool in surgical procedures, but
their use is still very limited.

Method: Literature review was undertaken using medline .Articles enumerating history and development of intelligent robots and their reporting data on applications were identified.

Background and history of intelligent robotic surgical system
Not more than 20 years back, The first such robotic assisted surgery was reported in the year 1994 built by Computer Motion Inc. which could automatically hold the television camera in the position desired by the surgeon[1] (Endoscopic surgery, Optimal positioning robot).

1. Introduction

Intelligent Robots are slowly and gradually in demand and can be considered an emerging technology in the field of surgery. However, Until now to incorporate intelligent robots in surgical procedures have been completely driven by the type of surgery. In addition, the leading role of developing intelligent robots are currently being taken up by Private sector. Whether or not intelligent robotic surgical system will grow into a more practical role is still in question.

In this study, we discuss the history, development of intelligent robotic surgical system and review such current intelligent systems, and finally we discuss the possible roles of intelligent robotic surgical system in the future.

It is our aim that by the end of this article the reader will be able to make a more logical and informed decision about intelligent robotic surgical system.

Table 1: List of Successful Surgical robotic systems

Reported by	**Surgery Type**	**Robotic System**	**Application -Driven**
Cohn et al., 1995	Orthopedic ,the placement of a hip prosthesis	ROBODOC(Integrated Surgical Systems)	The Robot could sculpt the acetabulum cavity, by means of milling cutter
Taylor et al., 1990	orthopedic, the placemnt of a hip prosthesis,	ORTHODOC(ROBODOC integrated with a vision and a remote control system).	Could perform remote operations with better accuracy than a surgeon's hand
D'Attellis et al., 2002; Reuthebuch et al., 2002; Austad et al., 2001	Endoscopic	DAVINCI and the ZEUS Robotic Surgical System(Evolution of AESOP Robot)	Operate through the remote transmission of clinical data for diagnoses and therapies (tele-surgery)
Harris et.al., 1997	Orthopedic(Knee surgery, Prostate resection)	ACROBOT ,PROBOT(Neuro-surgical clinics of Lausanne, London Imperial college)	Insert screws and nails in order to reduce fractures
Glauser et. al., 1995	Neurosurgery (stereotactic brain biopsy)	Minerva	Force sensors, nonlinear electrostimulation probe, and implantation of living encapsulated cells

P. Morgan et al., 2003; G. Deacon et al.., 2010; J. Brodie et. al., 2011	Neurosurgery	Pathfinder (prosurgics, formely Armstrong Healthcare Ltd.)	Using the system, the surgeon specifies a target and trajectory on a pre-operative medical image, and the robot guides the instrument into position with submillimeter accuracy. The system also guides needles for biopsy and guiding drills to make burr holes
L. Joskowicz et. al.,2011 ; D. P. Devito et al.,2010	spinal surgery, Brain Operations	Renaissance (Mazor Robotics, the first generation system was named SpineAssist)	The system provides tool guidance for procedures including deformity corrections etc. based on its software. Studies suggests more accuracy in implants than traditional methods
A. D. Pearle et al.,2010; V. Stueber et.al.,2009	Orthopedics	RIO robotic arm (MAKO surgical corp)	Implantation of lateral and medical unicondylar knee components, as well as for patellofemoral arthroplasty
C. Plaskos et al.,2005 ; Koulalis et al.,2010	Orthopedic	iBlock(Praxim Inc.)	Automated cutting guide for total knee replacement. Reduced surgical time and increased cut accuracy compared to navigation of cutting block by human surgeon.
G. Brisson et al.,2004,2008 ;	Orthopedic	Navio PFS(Blue Belt Technologies)	Uses intraoperative planning instead of CT Scan for unicondylar knee replacement
P. L. Yen et al.,2010	Orthopedic	The Stanmore Sculptor (Stanmore Implants)	Helps to keep the surgeon in planned workspace ,as has active constraints
G. H. Ballantyne, et al.,2002	Laproscopy	AESOP	It either moved the endoscopic under voice control or allowed the endoscope to be manually positioned.
K. Shah et al.,2011	Laparoscopy	Da Vinci Surgical system	Used for radical prostatectomy
M. Stark et. al.,2012	Laparoscopy	Telelap ALF-X (CE Mark 2011)	Four armed robotic –system .Endoscopic view and activation of various instruments controlled by eyetracking
A. Melzer et al.,2008	Percutaneous	InnoMotion (Synthes Inc.)	A robot arm used inside a CT or magnetic resonance imaging (MRI) Machine.

V. Y. Reddy et. al. 2007	Steerable Catheters	Sensei X (Hansen Medical)	It uses Intelligence force sensing to estimate the contact force by gently pulsing the catheter a short distance in and out of the steerable inner sheath and measuring force at the proximal end of the catheter. These forces are communicated through a vibratory feedback to the surgeon's hand
S. Ernst et al., 2004	Steerable catheters	Niobe (Stereotaxis, CE mark 2008)	It is a remote navigation system . It uses a magnetic field to guide the catheter tip.
J. R. Adler Jr. et al., 1997	Radiosurgery	CyberKnife (Accuray Inc.)	A Frameless radiosurgery system consisting of a robotic arm holding a linear accelerator, a patient table called by the RoboCouch, and an X-ray imaging system.
J. P. Rock,2004	RadioSurgery	The Novalis with TrueBeam STx (BrainLab Inc. and Varian Medical Systems)	A frameless system consisting of a linear accelerator and a micro-multileaf collimators for beam shaping
H. R. Halperin et. al.,2006	Emergency Response	AutoPulse Plus (ZOLL Medical Corp.)	The AutoPulse performs chest compressions by tightening the band rhythmically.
R. Seymour,2007	Prosthetics and Exoskeletons	C-leg(Otto Bock)	It adjusts the swing phase dynamics automatically and improve stability during the stance phase by controlling knee flexion.

2. Applications of artificial intelligence to medical robotics

The interest in biomedical applications of artificial intelligence rocketed after the creation of the SUMEX-AIM Computing resource at Stanford university, and a sister facility at Rutgers university, which used the then new ARPANET to make computing cycles available to a national and international researcher's community who wanted to add intelligence to medical and biological procedures.(Freiherr G.,1980)[24]

The main reason to incorporate intelligent robotics in common surgeries is to add new capabilities that can complement the surgeon's own skills .It is leading towards geometrically precise, image guided, and minimally invasive therapies, which can lead to better results, shorter recovery time, thus lowering the overall costs and the chances of repeated surgery is reduced. (Taylor, R.H. et al., 2002)[25].

One such application was the Simulation of surgical operations through the use of 'virtual reality' systems. (Elena Alessandri et al.,2003)[22]. The robot has to follow a trajectory in order to perform the surgical task, which is generated by an intelligent planner. The robotic simulator is fed with a trajectory which is used to show the user(surgeon), the simulation of action commanded to the system. Once the trajectory is completely checked, it can be fed to the medical robot to execute the operation.

Another application includes making sense out of medical image data. Procedures of cognitive analysis are being used to get the semantic meaning of the content in the image. Computer vision and intelligent information systems are used in advanced medical image analysis(Marek R. Ogiela et al.)[23]. Such systems are used for medical diagnosis, or multimedia data indexation based in semantic information.

Robotic vision system have been used to retrieve and position instruments used in laparoscopic surgeries automatically. A visual servoing algorithm is used to recover the instrument and move it into the center using feature errors in the image. (Krupa et al., 2003)[26].

Mechanical wrists have been also used to increase the efficiency and are used to replace the inaccurate and time-consuming techniques caused due to limited degree of motion thus enhancing the dexterity of the system (V. Falk et al., 1999)[27]. These surgeries uses teleoperation and the system uses machine intelligence to give the force feedback to feel the interaction between the system and the human tissue to remove conflicts between observed and actual instrument motions. (Madhani, A.J. et al.,1998)[28].

An electrosurgical system have also been developed which uses an intelligent selections system that is used by a surgeon to select the mode of operation by sending control signals which places the instrument in one of the operating electrosurgical modes.(__a patent__) . (Ellman,Alan G.,et al.,2003) [29].

Artificial intelligence has been used in Endo[PA]R (Endoscopic partially-autonomous robot) system to automate repeating manipulation tasks. It also has a display on his head which is used to provide stereo vision and user interaction is enhanced by feedback provided about the force being applied. This system can perform an unassisted knot-tying(Mayer H. et al.,2004) [30].

Unsupervised machine learning has been used in treatment of Parkinson's disease using deep brain stimulation surgery. There is a variation in patient's neurophysiology and recording condition, which limits the attempt to quantitate this process, using single computational measures of neural activity. Thus, machine learning came to rescue and is used to extract multiple computational features from the micro electrode neurophysiology and integrates it with the tools. The result is a color-coded map of neural activity. These maps are used to understand activity transition across anatomic boundaries of subcortical structures.(S Wong et al.,2009) [31].

Machine learning is used in treatment of breast cancer as it can diagnose cancer from processing medical images and deriving cytologic features from digital scan of fine-needle aspirate.(William H. Wolberg. et. al.,1994) [32].

Computer vision in robotic surgeries is now being replaced by online machine learning based feature tracking method that accelerates accurate estimation and tracking of dynamic tissue deformation leading to better navigation and intraoperative surgical guidance in minimally invasive surgeries.(Peter Mountney et al.,2008) [33].

Recurrent Neural network has find application to learn to tie knot in Robotic heart surgeries and thus leads to reduction in total surgery time.(HerMann Hayer et. al.,2008) [34].

Dynamic switching and real-time machine learning are being used for improved human control of assistive biomedical robots. Dynamic switching technique can learn during ongoing interaction to predict user behavior and hence presenting the most effective control option for a given task. (Pilarski, P.M. et. al.,2012) [35].

Supervised classification data mining are used to predict the outcome temporal lobe epilepsy surgery. The system can predict whether a patient with TLE secondary to hippocampal sclerosis will fully recover from epilepsy or not. (Rubén Armañanzas et. al.)[36].

3. Result

This paper reviews the use of artificial intelligence in medical robotics .Computer vision is being used to manipulate medical images and making sense of data in images. Machine learning and neural networks are used to learn from previous records and can predict that the outcome of a surgery will be effective or not. Feedback mechanism to predict the force between the instrument and the human tissue is sent to the doctor facilitating tele-surgery.

4. Future Prospects

Fully un-assisted surgeries are not yet completely used to treat patients .Autonomous surgical robots can be used in the future to perform surgeries on their own without the help of surgeons and our doctor in the future can be a fully autonomous robots that can make their own decisions.

Research at Stanford university have developed nano robots that can be swallowed by patients and they can navigate within the body of the patients using robotic hands and can give a view to the doctor to find a tumor or infected portions without making an incision . Thus facilitating reduced treatment time and more efficient method of surgery.

Intelligent micro instruments have also been developed that can predict and orient themselves in the right direction during operation and thus helping in making more effective cuts and incisions and making operations more efficient .

5. Conclusion

Artificial intelligence has revolutionized every field it has touched and its one such application has been found in medical robotics. Intelligence in robotics is still in nascent stages and fully autonomous surgeries are still not used in practice. Intelligent surgical departments are been formed in many parts of the world to accelerate research to integrate surgical robot with intelligence so that they can predict and make their own decisions in performing surgeries thus reducing the staying and healing time of patients and thus reducing the overall costs of surgeries in the future.

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