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Artificial Intelligence Technique for Robot Assisted Surgery: Opportunities and Challenges

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Abstract— Surgery, is a procedure done in modern medicine to identify, avoid and cure any impending ailment which could seriously affect the existence of any living being. Hence surgeries form a critical part of humans/animal in ensuring life or improvement in the current condition to lead a happy and a healthy life. Use of Artificial Intelligence as a part of decision support systems (AI) in order to improve the performance of specific tasks (by medical robots) is getting due attention as a part of technological intervention in health care. This paper attempts to highlight the evolution, limitation, opportunities and challenges in using AI based technologies in robot assisted surgeries. We also propose an AI based framework for anomaly detection and positioning of the surgical tool based on the data obtained from the processed images.

Keywords— Surgery, Artificial Intelligence, Medical Robot, Medical Image, Interest point

I. INTRODUCTION

As per the statistics worldwide close to 230 million major surgeries are performed every year. This leads to a great stress on the existing health care system. In this context , Robotic surgery, or robot-assisted surgery, is being widely used to operate surgical instruments especially in cases where surgical procedures are carried out in constrained space With the advancements in technology, innovation and the Information technology revolution, extensive use of robots in surgery shall be a reality in the years to come.

Artificial intelligence (AI) based technologies is involved in building smart machines capable of performing tasks that typically require human intelligence. Advances in computational power paired with massive amounts of data generated in healthcare systems make many clinical problems ripe for Artificial Intelligence based applications.

II. ARTIFICIAL INTELLIGENCE IN MEDICINE

A. Medical Research

AI can be used to analyze and identify patterns in large and complex datasets faster and more precisely than has previously been possible[1]. It can also be used to search the scientific literature for relevant studies, and to combine different kinds of data; for example, to aid drug discovery.

B. Clinical Care

Using AI to analyze clinical data, research publications, and professional guidelines could also help to inform decisions about treatment. Possible uses of AI in clinical care include:

1) *Medical Imaging*: Medical scans have been systematically collected and stored for some time and are readily available to train AI systems. AI could reduce the cost and time involved in analyzing scans, potentially allowing more scans to be taken to better target treatment. AI has shown promising results in detecting conditions such as pneumonia, breast and skin cancers, and eye diseases.
2) *Echocardiography*: AI is being currently used to analyze echocardiography scans that detect patterns of heartbeats and diagnose coronary heart disease.
3) *Screening for Neurological Conditions*: AI tools are being developed that analyze speech patterns to predict psychotic episodes and identify and monitor symptoms of neurological conditions such as Parkinson's disease.
4) *Patient and Consumer-Facing Applications:* Several apps that use AI to offer personalized health assessments and home care advice are currently on the market. Information tools or chat-bots driven by AI are being used to help with the management of chronic medical conditions. AI apps that monitor and support patient adherence to prescribed medication and treatment have been trialed with promising results.
5) *Public Health*: AI has the potential to be used to aid early detection of infectious disease outbreaks and sources of epidemics, such as water contamination. AI has also been used to predict an adverse drug reaction which is a key metrics to measure drug efficacy and also a major reason for admissions to hospitals.

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III.EVOLUTION OF ROBOT BASED SURGERY

Although the idea of using Robots was mooted in the early 1980's, its extensive usage in what is called as "Minimum Invasive Robotic Surgery" was seen in the late 90's. This change can be attributed to the recent advances in technology that have lead to more reliability, and therefore wider acceptance by the general populace and the medical community [2]. The progression has been from the traditional techniques to the minimal invasive surgery to the minimally invasive robotic surgery. There were many benefits of minimally invasive techniques over traditional techniques, which was immediately apparent to both surgeons and patients. The tiny incisions lead to lower risk of infection and less recovery time after surgery. Surgeons especially liked the precision and enhanced vision that this provided [3]. . The Minimal invasive surgery also has its limitations. Some of the more prominent limitations involve the technical nature of the apparatus used in surgeries

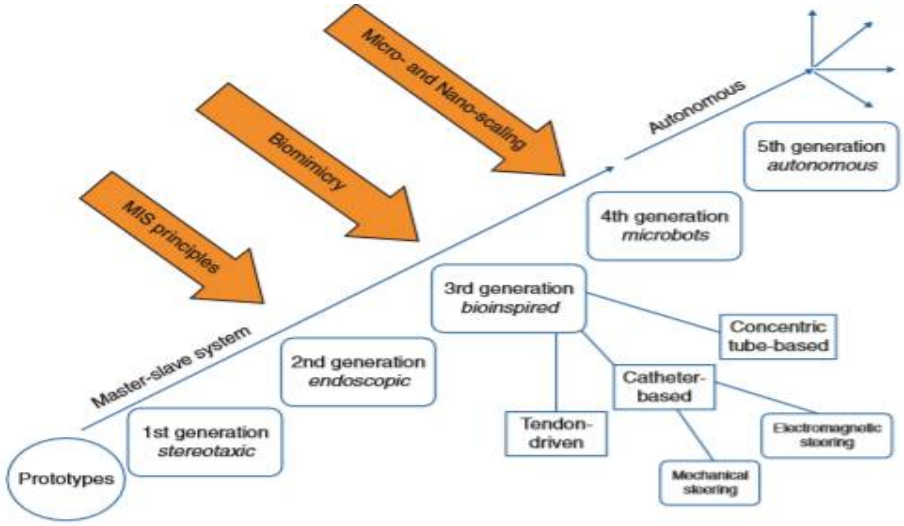


Fig2. Evolution of Robot based Surgery

IV. ROLE OF AI IN ROBOT ASSISTED SURGERY

In order to identify the point of surgery it is critical to analyze the point of anomaly. This information, on verification by the surgeon, can then be used to perform the necessary remedial procedure. Using computer vision and image processing techniques coupled with the intelligent algorithms the entire process of anomaly detection to movement of the surgical tool to the point of interest can be done swiftly and accurately. However, all of these operations are carried out in the presence of medical expert or a surgeon.

V. TECHNOLOGIES IN ROBOT ASSISTED MINIMUM INVASIVE SURGERY

A. Computer Vision

Computer vision is an interdisciplinary scientific field that deals with how computers can gain high-level understanding from digital images or videos. Computer vision tasks include methods for acquiring, processing, analyzing and understanding digital images, and extraction of high-dimensional data from the real world in order to produce numerical or symbolic information. The image data can take many forms, such as video sequences, views from multiple cameras, multi-dimensional data from a 3D scanner, or medical scanning device.

The 5 major computer vision techniques can help a computer extract, analyze, and understand useful information from a single or a sequence of images are image classification, object detection, object tracking, semantic segmentation, instance segmentation.

B. Interest Point Detection

Interest point detection is a recent terminology in computer vision that refers to the detection of interest points for subsequent processing. Interest point detection is a process of detecting the expressive texture which made us to distinguish the features.

C. Advantages of Robot Assisted Surgery

With the robotic arm eliminating the natural limits of human wrists, surgery can be performed with more delicate, precise and efficient movements. The 3D imaging and endowrist technology of robots ensure surgery is more accurate, nerve bundles are

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dissected more precisely, erectile function is preserved, and there is a better chance of cure than with non-robotic surgery. The surgeon also enjoys more strength, dexterity, flexibility, control and a better view of the operated area. Robotic surgery allows the surgeon to get more comfortable, perform the procedure with increased concentration and focus, and can undertake complex procedures that are tougher or impossible with other techniques.

D. Disadvantages of Robot Assisted Surgery

With robot-assisted surgery, there is not only the risk of human error when operating the robotic system, but also the potential for mechanical failure. For instance, system components such as robotic arms, camera, robotic tower, binocular lenses and instruments can fail. In other cases, the electrical current in the robotic instrument can leave the robotic arm and be misapplied to surrounding tissues, resulting in accidental burn injuries. Likewise, robot-assisted surgery can cause nerve palsies due to extreme body positioning or direct nerve compression that may occur when using robots. It also takes longer to perform robotic surgery than non-robotic surgery in surgical centers with lower robotic volume or by less experienced surgeons.

E. Limitation, Challenges and Opportunities

Several authors [4, 5, 6 and 7] have indicated the challenges and opportunities in the implementation of the robots for surgery. Broadly these are

1) *Economic Viability:* All though the superiority of Robot assisted MIS is undisputed, the cost of development and usage of these systems is on the higher side. However, Whilst it is clear that robotic surgery costs remain high compared with open and MIS cases, there is increasing evidence to suggest the long-term cost efficacy of robotic approaches compared with traditional open operations
2) *Learning Curve:* With the advancement of the technologies and with the skilled surgeons available , the learning curve could be substantially reduced However developing the knowledge base to be utilized and continuous learning to be adopted to build effective surgical systems remains a challenge
3) *Operational Limitations:* These limitations primarily are on the space available to install these devices, ergonomics of the space, Skill of the personal using these systems. However these cam ne mitigated with the technological advances and wide spread awareness of these systems.

The other limitations can include the Intellectual Property rights, ethical and moral issues and the acceptability of these systems not only the management of clinics/hospital (from the cost point of view) but also the medical fraternity at large.

F. Role of AI in Robot Assisted Surgery

As described in the earlier sections AI is increasingly being used in modern health care starting from clinical research, drug discovery, pre and post-operative management etc. However in the case of AI based Robot assisted surgery, some of the potential areas where AI could find its use include

1) *Automation of Suturing:* AI based technologies can asset in Automation reducing the length of surgical procedures and surgeon fatigue.
2) *AI based Evaluation of Surgical Skills:* Based on the data collected on data collected from suturing performance and classified surgeons AI can be used to evaluate and provide insights on the surgical skills. Some of the parameters for such evaluation include Completion time, Path length, Depth perception, Speed, Smoothness and Curvature
3) AI technologies can be used in the selection and properties enhancement based research of Surgical Robotic Materials
4) *AI for Surgical Flow Modelling:* AI based technologies can aid in Improving the efficiency of surgery by aiding the surgeon in the pre- and post-operative procedures.

G. AI Techniques for Interest Point Detection

Interest points in an image can be identified by various methods of artificial intelligence by Deep Learning technique called Convolution Neural Network and use of the Boltzmann family machines and the stacked DE Noising auto encoders. CNN have the unique capability of learning things automatically based on the given datasets, and also invariant to transformations, which is greater asset for certain computer vision applications. CNN can reduce lot of computational because it doesn't need to visit the pixels by pixels instead it uses filters. It can be concluded that CNN can accomplish the desired result in deep learning problems with image inputs.

H. Our Framework

In this case, we propose a frame work which essentially looks at reducing the learning by using Automated Data Analysis using parallel coordinate plots. These plots are primarily used to map the objectives with the various inputs to understand their individual and collective effect on the quality of the surgery. The insights and the subsequent learning from this system can be

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effectively used to hasten the understanding of the intricacies in the surgical procedure and also enable the system to be effectively work with minimum human supervision.

VI. METHODOLOGY OF THE RESEARCH

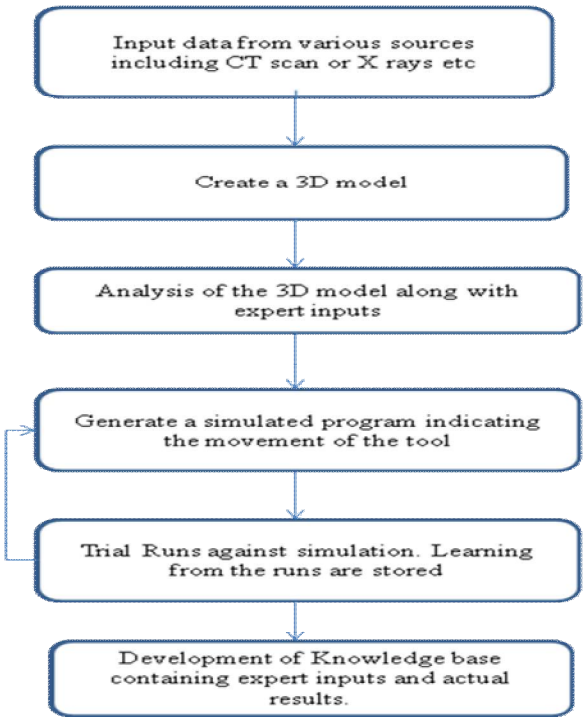


Fig2. Methodology

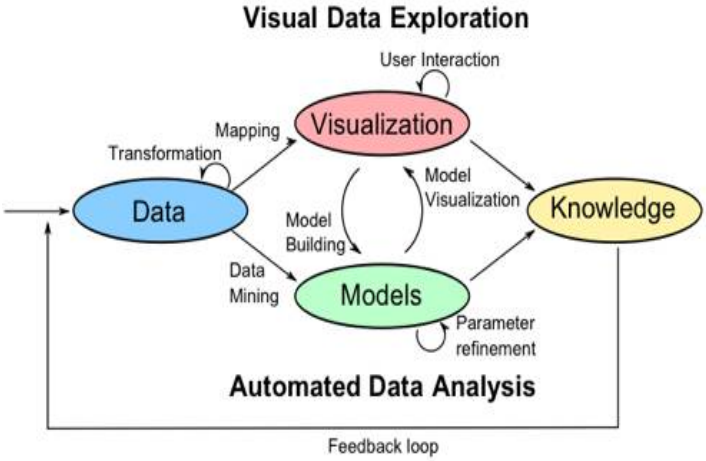


Fig 3. Visual Data Exploration

The methodology clearly indicates the procedure of simulating a surgical process and the coordination between the insights obtained from the process data and the surgical manoeuvring of the surgical tool/s under the supervision of experienced surgeon. The learning based on the decision taken by the surgeon is stored and this in turn serves as a knowledge base for the robot for subsequent surgeries.

The miniature model of such an arrangement is shown below. Currently the location of anomaly is found out based on the CT scan or any image provided. The positional accuracy is being tested and the initial results are encouraging.

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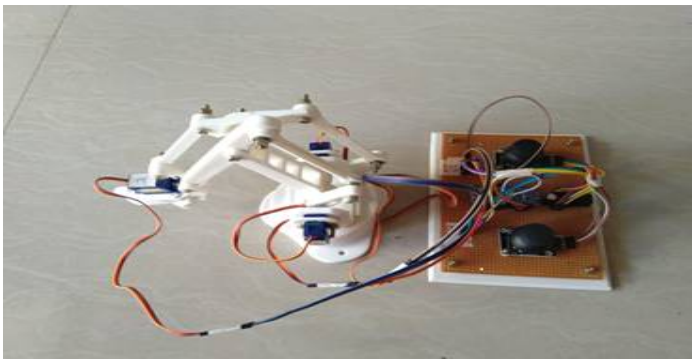


Fig 4. Prototype of the Robot

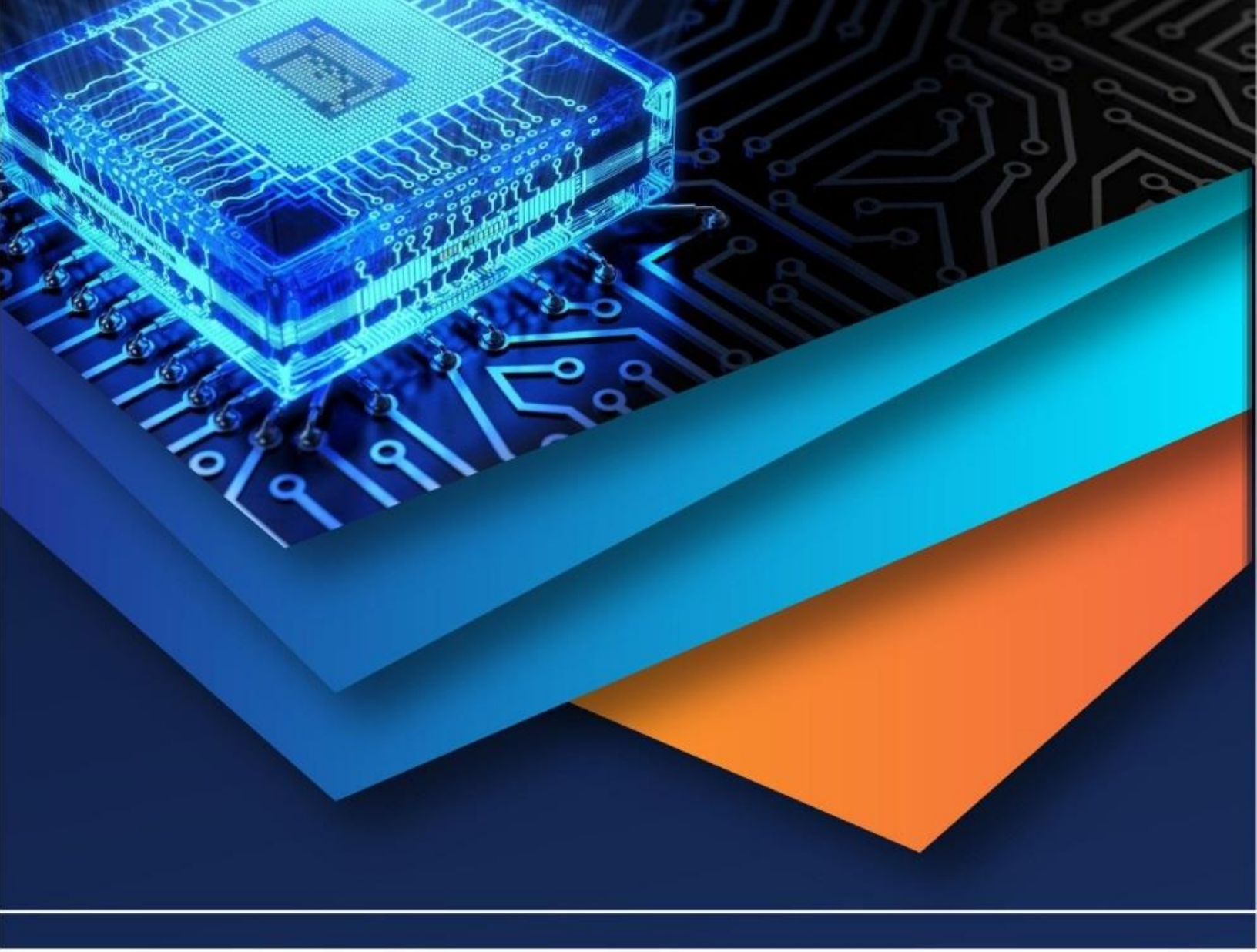
VII. CONCLUSION

In conclusion the potential application of AI in the surgical field is diverse and addresses multiple points along the surgical spectrum including training, operations and clinical data management. Innovations which can prove their worth over the long haul by consistently saving surgeon's time. The model built on the basis of this framework is being tested for its efficacy and efficiency and the initial results are encouraging. However several critical images and the subsequent position of the tool is to be tested.

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