

Artificial Intelligence based Robotic- Surgery Assistive System

Submitted in partial fulfillment of the requirements for the award of Master
of Technology degree in Medical Instrumentation

by

ASHWATHI H (41440003)



**DEPARTMENT OF BIOMEDICAL ENGINEERING
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project report is the bonafide work of Ashwathi H (Reg. No. 41440003) who carried out the project entitled "Artificial Intelligence based Robotic-Surgery Assistive System" under my supervision from November 2022 to April 2023.

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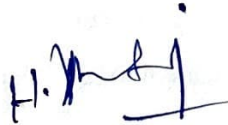
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DECLARATION

I, **Ashwathi H** (Reg. No. **41440003**) hereby declare that the Project report entitled "**Artificial Intelligence based Robotic-Surgery Assistive System**" done by me under the guidance of **Dr. J Premkumar, Ph.D.**, Department of Biomedical Engineering is submitted in partial fulfillment of the requirements for the award of **Master of Technology** degree in **Medical Instrumentation**.

DATE: 5/05/2023

PLACE: Chennai



SIGNATURE OF THE CANDIDATE

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CHAPTER 1

INTRODUCTION

Surgical systems that will further revolutionize the field of medicine. [4] Artificial Intelligence (AI) and Robotics are two rapidly developing fields that have been transforming various industries, including healthcare. In recent years, there has been a significant increase in the use of AI and Robotics in medical settings, particularly in surgical procedures. Robotic surgical systems are being used increasingly to enhance surgical precision, reduce recovery time, and minimize complications.[1] The integration of AI in surgical robotics has opened up new avenues for the development of intelligent assistive systems that can perform surgeries with greater accuracy, speed, and safety. An Artificial Intelligence-based Robotic Surgical Assistive System is a technology that combines the power of Robotics and AI to provide surgeons with a highly advanced surgical assistant. This system can take input from various sources, including pre-operative imaging, real-time surgical data, and patient vital signs, to provide precise, real-time guidance to the surgeon. The system can also perform certain surgical tasks automatically, reducing the workload on the surgeon and improving surgical outcomes.[2]

The use of AI-based robotic surgical assistive systems is becoming increasingly popular in various surgical specialties, including neurosurgery, orthopedics, and urology. These systems can help surgeons to perform complex procedures with greater precision, speed, and safety, thereby reducing the risk of complications and improving patient outcomes. Additionally, these systems can provide surgeons with real-time feedback, allowing them to make more informed decisions during the surgical procedure.[3] Overall, the integration of AI and Robotics in surgical procedures has transformed the way surgery is performed. The development of AI-based robotic surgical assistive systems represents a major leap forward in the field of surgical robotics, and has the potential to significantly improve surgical outcomes while reducing the risk of complications. As these technologies continue to advance, we can expect to see even more sophisticated and intelligent[4].

The use of AI-based robotic surgical assistive systems has several benefits over

traditional surgical techniques. One of the primary advantages is increased precision. Robotic systems can perform movements with much greater accuracy and precision than a human hand, which is especially important in delicate surgical procedures. Additionally, the use of AI can further enhance precision by providing real-time guidance to the surgeon based on a wealth of data.[5] Another advantage of AI-based robotic surgical assistive systems is reduced recovery time. Robotic systems can perform surgeries with smaller incisions, resulting in less tissue damage and a faster recovery time for the patient. Additionally, the use of robotics can reduce the risk of complications during surgery, such as infection or bleeding, which can also contribute to a shorter recovery time. Furthermore, AI-based robotic surgical assistive systems can provide a safer surgical environment. The systems can detect potential complications in real-time and alert the surgeon, allowing them to take corrective action quickly.[6] Additionally, the use of robotics can reduce the risk of human error during surgery, further improving patient safety. Despite the numerous advantages of AI-based robotic surgical assistive systems, there are also some potential drawbacks. One concern is the cost of these systems, which can be quite high, making them inaccessible to some medical facilities. Additionally, there may be a learning curve for surgeons who are not familiar with the technology, which could potentially affect surgical outcomes. In conclusion, AI-based robotic surgical assistive systems represent a major advancement in surgical technology. These systems can improve surgical precision, reduce recovery time, and enhance patient safety. As these technologies continue to evolve, we can expect to see even more advanced and sophisticated surgical systems that will further transform the field of medicine.

1.1 Definition of Robotic Surgical Assistive System:

A robotic surgical assistive system (RSAS) is a type of surgical technology that uses robotic devices to assist in surgical procedures. The system consists of a set of computer-controlled devices that are used to perform surgical procedures with greater precision and accuracy than traditional surgical methods. RSAS has revolutionized the field of surgery and is rapidly becoming the preferred method for many procedures.[8] The system is made up of several components that work together to allow for precise surgical maneuvers. These include a surgical

console, robotic arms, and an endoscope. The surgical console is where the surgeon sits and controls the robotic arms. The robotic arms are equipped with surgical instruments that are inserted into the patient's body through small incisions. The endoscope is a small camera that provides the surgeon with a magnified, high-definition view of the surgical site. The RSAS uses a variety of sensors and cameras to provide the surgeon with a real-time view of the surgical site. This allows for greater accuracy and precision, as the surgeon can see exactly what they are doing and can adjust their movements accordingly.[9] Additionally, the robotic arms can move in ways that human hands cannot, allowing for greater flexibility and range of motion during surgery. One of the primary benefits of the RSAS is that it can reduce the risk of complications during surgery. Since the system allows for greater precision and accuracy, there is less chance of damage to surrounding tissues and organs. Additionally, the system can perform procedures with smaller incisions, which can lead to less pain, scarring, and a faster recovery time for the patient. The use of the RSAS is rapidly expanding, and it is now used for a wide range of procedures, including cardiac surgery, urologic surgery, gynecologic surgery, and gastrointestinal surgery. As technology continues to improve, the RSAS is likely to become even more precise and accurate, leading to better outcomes for patients and greater adoption by surgeons.[10]

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Robotic surgical assistive systems are usually controlled by the surgeon through a console or workstation located in the operating room. The surgeon uses a set of master controls to manipulate the robotic arms, which are equipped with surgical instruments such as scalpels, scissors, forceps, and cautery devices. The robotic arms can rotate and bend in a variety of ways, providing the surgeon with greater dexterity and control than is possible with traditional surgical instruments. In addition to the greater precision and accuracy offered by RSAS, there are several other potential benefits. For example, the system can reduce the amount of blood loss during surgery, since the robotic instruments can cauterize blood vessels as they cut. The system can also minimize the risk of infection, since the small incisions made by the instruments heal more quickly than large incisions. Despite these benefits, there are also some potential drawbacks to RSAS. One of the main concerns is the cost of the technology, which can be prohibitively expensive for many hospitals and surgical centers.[11] Additionally, there is some concern that the use of RSAS may lead to a decrease in surgical skills among human surgeons, as the technology takes over many of the manual tasks previously performed by the surgeon. The use of robotic surgical assistive systems represents a major advance in surgical technology, offering greater precision, accuracy, and safety than traditional surgical methods. While the technology is not without its challenges and concerns, it is likely to continue to be adopted by surgeons around the world as a preferred method for many types of surgical procedures.

1.2 History and evolution of Robotic Surgical Assistive System:

The history and evolution of robotic surgical assistive systems date back to the 1980s when the first robotic surgical system was developed by the US Army. This

system was designed to help surgeons perform delicate surgical procedures from a remote location. However, it was not until the early 2000s that the first robotic surgical system was approved by the US Food and Drug Administration (FDA) for use in clinical settings. The first FDA-approved robotic surgical system was the da Vinci Surgical System, developed by Intuitive Surgical. The da Vinci system was designed to assist surgeons in performing minimally invasive surgeries. It features a robotic arm that holds surgical instruments and a camera that provides a three-dimensional view of the surgical site.[12] Since then, several other companies have developed robotic surgical systems, including the **MAKO** Surgical System, the ROSA Surgical System, and the Senhance Surgical System. These systems are used to perform a wide range of surgical procedures, including urologic, gynaecologic and cardiovascular surgeries. The evolution of robotic surgical systems has been driven by advances in technology, including improvements in imaging, computer graphics, and robotic control systems. Modern robotic surgical systems are equipped with advanced imaging systems that provide surgeons with highly detailed images of the surgical site. They also feature advanced control systems that allow surgeons to manipulate surgical instruments with a high degree of precision. Despite the many advantages of robotic surgical systems, there are also some limitations. For example, they can be expensive to acquire and maintain, and they require specialized training to use effectively. However, as technology continues to advance, it is likely that robotic surgical systems will become more widely available and more affordable, making them an increasingly important tool for surgeons around the world.[13]

Artificial Intelligence (AI) has revolutionized the medical industry by introducing Robotics in the surgical field. The concept of Robotic Surgical Assistive System (RSAS) has been evolving since the early 1980s when the first robot, the PUMA 560, was introduced for surgical. Since then, there has been a significant evolution in the design, functionality, and application of RSAS. In the early days, RSAS was mainly used for minimally invasive procedures, including laparoscopy, arthroscopy, and hysteroscopy. These procedures involved making small incisions in the patient's body and using small cameras and instruments to perform the surgery. The PUMA 560 was used as a tool to hold and manipulate these instruments.[14] The system was tele operated, which means the surgeon would control the robot from a

distance. In the 1990s, RSAS evolved with the introduction of the da Vinci Surgical System by Intuitive Surgical. This system was designed to provide a more accurate and precise surgical approach. The da Vinci system incorporated an advanced teleoperation system that allowed the surgeon to control the robot's movements with a high degree of accuracy. The system also provided 3D imaging capabilities that allowed the surgeon to view the surgical field in high resolution, enabling better visualization and precision. The latest RSAS models integrate AI algorithms, allowing the system to learn and adapt to different surgical scenarios, improving the surgical outcomes. AI-based RSAS enables the surgeon to program the robot to perform specific tasks, and the system can make real-time adjustments to the procedure, allowing for better outcome.[15]

1.3 Role of Artificial Intelligence in Robotic Surgical Assistive System:

Robotic surgical assistive systems (RSAS) have transformed the field of surgery by allowing for greater precision, control, and accuracy during surgical procedures. One of the key components that enables RSAS to function effectively is artificial intelligence (AI). AI plays a crucial role in RSAS by providing the system with the ability to learn and adapt to various surgical scenarios. Through the use of machine learning algorithms, the system can analyze vast amounts of data and quickly identify patterns, enabling it to make informed decisions and perform complex surgical maneuvers. One of the most significant benefits of AI in RSAS is its ability to assist surgeons in real-time during surgery. The system can monitor the patient's vital signs, such as blood pressure, heart rate, and oxygen saturation, and alert the surgeon if there are any anomalies that require immediate attention.[16] Additionally, the AI can provide the surgeon with a 3D image of the surgical field, which allows for better visualization of the area being operated on. AI also enables RSAS to perform complex surgical procedures that would be difficult, if not impossible, for a human surgeon to accomplish. For example, the system can perform microsurgery with precision down to a few micrometers, enabling the surgeon to operate on delicate tissues with minimal damage. Another benefit of AI in RSAS is its ability to reduce the risk of human error. Unlike human surgeons who may experience fatigue, stress, or other factors that can impact their performance, the AI in RSAS is always alert and able to perform at peak efficiency. In conclusion, the role of AI in RSAS is critical

to the success of the system. By providing the system with the ability to learn, adapt, and make informed decisions in real-time, AI enables RSAS to perform complex surgical procedures with precision and accuracy, while reducing the risk of human error. The use of AI in RSAS represents a significant advance in the field of surgery and has the potential to revolutionize the way we approach medical procedures in the future.[17]

1.4 AI-based algorithms used in Robotic Surgical Assistive System:

Robotic Surgical Assistive Systems (RSAS) utilize a range of AI-based algorithms to enhance surgical precision, accuracy, and safety. Some of the AI-based algorithms used in RSAS include:

Machine learning algorithms: These algorithms can be used to recognize patterns in medical images, such as CT scans and MRIs, and assist surgeons in making more accurate incisions and avoiding critical structures. Machine learning algorithms can also be trained to recognize and predict surgical outcomes based on a patient's medical history.

Neural networks: Neural networks can be used to analyze large amounts of data generated during a surgical procedure, such as sensor readings, video feeds, and vital sign measurements. The data can be analyzed in real-time to provide feedback to the surgeon on the progress of the surgery and assist in decision-making.

Natural Language Processing (NLP): NLP can be used to translate spoken commands from the surgeon into actions performed by the RSAS. This can be especially helpful when the surgeon needs to perform a specific action quickly, and verbal communication is faster than manually inputting commands.

Computer vision: Computer vision algorithms can be used to detect and track the position of surgical instruments, as well as provide feedback on the amount of pressure being applied to the tissue. Computer vision can also be used to identify anatomical structures in real-time, assisting the surgeon in identifying critical structures and avoiding complications.

Planning algorithms: Planning algorithms can be used to generate a roadmap of the surgical procedure, taking into account the patient's anatomy, surgical plan, and surgeon's preferences. The roadmap can be used to guide the RSAS in performing specific actions during the surgery and ensuring that the surgical plan is executed

precisely.

Motion planning algorithms: Motion planning algorithms can be used to generate smooth and efficient paths for the robotic arms of the RSAS to move along. These algorithms take into account the geometry of the surgical site, the position of the instruments, and other factors to ensure that the robotic arms move smoothly and do not collide with any other objects in the surgical field.

Control algorithms: Control algorithms can be used to ensure that the robotic arms of the RSAS move precisely and accurately. These algorithms take into account the feedback from sensors and other sources to adjust the position, orientation, and movement of the instruments in real-time.

Decision support algorithms: Decision support algorithms can be used to assist surgeons in making complex decisions during a surgical procedure. For example, these algorithms can analyze patient data and recommend the best course of action for a particular surgical task or alert the surgeon to potential complications.

Deep learning algorithms: Deep learning algorithms can be used to analyze large datasets of surgical procedures and outcomes to identify patterns and relationships between different factors. This information can be used to develop new surgical techniques, improve existing techniques, and enhance the overall quality of surgical care.

Reinforcement learning algorithms: Reinforcement learning algorithms can be used to train the RSAS to perform specific tasks. These algorithms use feedback from the surgical team to adjust the behavior of the RSAS and improve its performance over time.

In summary, AI-based algorithms are an essential component of Robotic Surgical Assistive Systems, providing a range of capabilities that enhance surgical precision, accuracy, and safety. These algorithms continue to evolve and improve, offering significant benefits to patients, surgeons, and healthcare systems as a whole.[19]

1.5 Machine learning techniques in Robotic Surgical Assistive System:

Robotic Surgical Assistive Systems (RSAS) are becoming increasingly common in surgical procedures, and machine learning techniques are being utilized to improve

their performance. Machine learning refers to the ability of a computer to learn from data and improve its performance over time without being explicitly programmed. One application of machine learning in RSAS is to improve the accuracy of the system's tracking of surgical instruments and tissue. This is typically done using computer vision algorithms that can identify and track the movement of surgical instruments in real-time. Machine learning techniques, such as deep learning and convolutional neural networks, can be used to train these algorithms to recognize different surgical instruments and tissue types and track them more accurately. Another application of machine learning in RSAS is to improve the system's ability to predict surgical outcomes. This involves analyzing data from past surgeries to identify patterns and relationships between different variables, such as the patient's age, health status, and surgical technique used.[20] Machine learning algorithms can then be trained on this data to predict the likelihood of certain outcomes, such as post-operative complications or the need for additional surgery.

Machine learning can also be used to optimize the control algorithms used in RSAS. This involves using data from previous surgeries to identify the most effective control parameters for the system, such as the speed and force of the robotic arm. Machine learning algorithms can be used to analyze this data and make predictions about which control parameters will produce the best outcomes in future surgeries. Overall, machine learning techniques are playing an increasingly important role in the development and optimization of RSAS. By analyzing and learning from data, these techniques can help improve the accuracy, safety, and effectiveness of robotic surgical assistive systems, ultimately leading to better patient outcomes. Machine learning techniques are also being used to improve the training of surgeons and to develop better surgical simulators.[21] One approach is to use virtual reality (VR) simulations to train surgeons on different surgical procedures. Machine learning algorithms can be used to analyze data from these simulations and provide feedback to the surgeon, such as the accuracy and speed of their movements, which can help them improve their skills. Additionally, machine learning is being used to develop more sophisticated autonomous systems for use in RSAS. These systems can analyze surgical data in real-time and make decisions about how to adjust the surgical instruments or assist the surgeon. For example, a system might detect when a surgeon is about to make a mistake and adjust the position of the

surgical instrument to prevent an error from occurring. Finally, machine learning can be used to improve the overall efficiency of RSAS. For example, machine learning algorithms can be used to optimize the scheduling of surgeries and the allocation of resources within the surgical team. This can help reduce wait times for patients and improve the overall quality of care. Overall, machine learning techniques are a critical component of the continued development and improvement of RSAS.[22] As the field continues to evolve, we can expect to see even more advanced machine learning algorithms being used to optimize and enhance this system.

1.6 Deep learning in Robotic Surgical Assistive System:

Deep learning is a subfield of machine learning that involves training artificial neural networks to learn from data and make predictions or decisions. It has numerous applications in artificial intelligence, including the development of robotic surgical assistive systems. Deep learning has become an important tool in the field of robotics, particularly in the development of robotic surgical assistive systems. These systems use machine learning algorithms to analyze data from various sources, including medical images, to assist surgeons in performing surgical procedures with greater accuracy and precision. One example of a deep learning application in robotic surgery is the use of convolutional neural networks (CNNs) to analyze medical images and identify structures such as blood vessels and tumors. By automating this process, surgeons can quickly and accurately locate important structures during a procedure, reducing the risk of complications and improving patient outcomes.[23] Another area where deep learning is being applied in robotic surgery is in the development of predictive models that can help guide surgical interventions. For example, deep learning algorithms can be used to analyze patient data and predict the likelihood of complications during a surgical procedure, allowing surgeons to make more informed decisions and adjust their approach accordingly. Finally, deep learning is also being used to improve the overall efficiency and effectiveness of robotic surgical systems. By analyzing data from previous surgical procedures, machine learning algorithms can identify patterns and optimize surgical workflows, reducing the time required for procedures and improving outcomes for patients. Overall, deep learning is an exciting and rapidly evolving area of research in the field of robotic surgical assistive systems, with significant potential to improve the accuracy, efficiency, and safety of surgical procedures.

1.7 Comparison of AI-based Robotic Surgical Assistive System with human surgeons:

- Robotic surgical assistive systems are becoming increasingly popular in modern surgical procedures, as they offer numerous advantages compared to traditional surgical techniques. These AI-based systems allow for greater precision, accuracy, and control during surgery, which can result in reduced complications, faster recovery times, and improved outcomes for patients. However, it is important to compare these systems to human surgeons to understand the full extent of their benefits and limitations.[26]
- Advantages of AI-based Robotic Surgical Assistive Systems One of the primary advantages of AI-based robotic surgical assistive systems is their precision and accuracy. These systems use advanced algorithms and sensors to provide real-time feedback and guidance to the surgeon, allowing for precise and accurate
- Another advantage of AI-based robotic surgical assistive systems is their ability to perform complex procedures with greater ease and efficiency than human surgeons. For example, robotic systems can access hard-to-reach areas and perform intricate tasks with greater ease than a human hand can. This can lead to shorter surgery times and reduced recovery times for patients.

In addition, AI-based robotic surgical assistive systems can help to reduce the physical strain on human surgeons. Surgery can be physically demanding, especially for procedures that require prolonged periods of standing and repetitive movements. By using robotic systems, surgeons can avoid these physical strains, which can help to reduce fatigue and improve their overall performance.[27]

CHAPTER 2

LITERATURE REVIEW

Despite the extensive published literature on the significant potential of artificial intelligence (AI) there are no reports on its efficacy in improving patient safety in robot-assisted surgery (RAS). The purposes of this work are to systematically review the published literature on AI in RAS, and to identify and discuss current limitations and challenges. literature research was conducted on PubMed, Web of Science, Scopus, and IEEE explore according to PRISMA 2020 statement. Eligible articles were peer-review studies published in English language from January 1, 2016 to December 31, 2020. Amstar 2 was used for quality assessment. Risk of bias was evaluated with the Newcastle Ottawa Quality assessment tool. Data of the studies were visually presented in tables using SPIDER tool. Thirty-five publications, representing 3436 patients, met the search criteria and were included in the analysis. Precision for surgical tools detection varied from 76.0% to 90.6%. Mean absolute error on prediction of urinary continence after robot-assisted radical prostatectomy (RARP) ranged from 85.9 to 134.7 days. Accuracy on prediction of length of stay after RARP was 88.5%. Accuracy on recognition of the next surgical task during robot-assisted partial nephrectomy (RAPN) achieved 75.7%. The reviewed studies were of low quality. The findings are limited by the small size of the datasets. Comparison between studies on the same topic was restricted due to algorithms and datasets heterogeneity. There is no proof that currently AI can identify the critical tasks of RAS operations, which determine patient outcome. There is an urgent need for studies on large datasets and external validation of the AI algorithms used. Furthermore, the results should be transparent and meaningful to surgeons, enabling them to inform patients in layman's words.[29]. **Andrea Moglia et.al (2021)**

Artificial intelligence (AI) and machine learning (ML) have emerged as disruptive technologies with the potential to drastically affect clinical decision making in spine surgery. AI can enhance the delivery of spine care in several arenas: (1) preoperative patient workup, patient selection, and outcome prediction; (2) qua

lity and reproducibility of spine research; (3) perioperative surgical assistance and data tracking optimization; and (4) intraoperative surgical performance.

The purpose of this narrative review is to concisely assemble, analyze, and discuss current trends and applications of AI and ML in conventional and robotic-assisted spine surgery. The majority of the published AI literature in spine surgery has focused on predictive analytics and supervised image recognition for radiographic diagnosis. Several investigators have studied the use of AI/ML in the perioperative setting in small patient cohorts; pivotal trials are still pending. Artificial intelligence has tremendous potential in revolutionizing comprehensive spine care. Evidence-based, predictive analytics can help surgeons improve preoperative patient selection, surgical indications, and individualized postoperative care. Robotic-assisted surgery, while still in early stages of development, has the potential to reduce surgeon fatigue and improve technical precision.[30] **Jonathan J. Rasouli, MD et.al (2021)**

Artificial intelligence (AI) has recently achieved considerable success in different domains including medical applications. Although current advances are expected to impact surgery, up until now AI has not been able to leverage its full potential due to several challenges that are specific to that field. This review summarizes data-driven methods and technologies needed as a prerequisite for different AI-based assistance functions in the operating room. Potential effects of AI usage in surgery will be highlighted, concluding with ongoing challenges to enabling AI for surgery. AI-assisted surgery will enable data driven decision-making via decision support systems and cognitive robotic assistance. The use of AI for workflow analysis will help provide appropriate assistance in the right context. The requirements for such assistance must be defined by surgeons in close cooperation with computer scientists and engineers. Clinical implications arise from the aim of assistance, but not replacement of surgical expertise. Decision support systems will recommend, not make, a decision. Cognitive robots will perform autonomous actions only as requested by surgeons. Less experienced surgeons will need this support more often than experienced surgeons. However, in the end, all AI assistance has to improve patient outcomes to be effective.[31] **Sebastian Bodenstedt et.al (2020)**

Artificial Intelligence is both the intelligence of machine, electronics and the branch of Computer which aim to create it. AI has produced many significant and impressive products even at this early stage in its development. Although no one can predict

the future in details, it is clear that computers with human-level intelligence would have a huge impact on our everyday lives and on the future course of civilization. Robot simply acts as an active agent whose environments the physical world the active part rules out rocks, the artificial part rules out pure software agents or soft bots, whose environment consists of computer, file systems, database and networks. In this paper, the concepts of surgical robots, how robotically assisted brain surgery performed and their benefits are discussed. The first generations of surgical robots are already being installed in a number of operating rooms around the world. Compared with traditional surgery, the Robotically-assisted brain surgery is very useful. The current development within the fields of surgical robots, robotically assisted heart surgery described here is a step in right direction. The robotic surgeon as da Vinci Surgical System and ZEUS Robotic Surgical System play an important role in heart surgery system. The surgeon is always in control during the brain surgery, there is no chance that the robotic arms will move on their own. That is very safe. The robotically assisted brain surgery plays an important role in the medical field. In future, improvement in the developments in robotic surgery will be seen.[32] **Jerwin Prabu et.al (2014)**

Technological innovations such as artificial intelligence and robotics may be of potential use in telemedicine and in building capacity to respond to future pandemics beyond the current COVID-19 era. Our international consortium of interdisciplinary experts in clinical medicine, health policy, and telemedicine have identified gaps in uptake and implementation of telemedicine or telehealth across geographic and medical specialties. This paper discusses various artificial intelligence and robotics-assisted telemedicine or telehealth applications during COVID-19 and presents an alternative artificial intelligence assisted telemedicine framework to accelerate the rapid deployment of telemedicine and improve access to quality and cost- effective healthcare. We postulate that the artificial intelligence assisted telemedicine framework would be indispensable in creating futuristic and resilient health systems that can support communities amidst pandemics. To summarize, AI and robotics could play an important role in providing telemedicine services during an outbreak or public health emergency while limiting exposure to healthcare workers and health systems.[33] **Sonu Bhaskar et.al (2020)**

This paper aims to move the debate forward regarding the potential of AI and autonomous robotic surgery with a particular focus on ethical and legal aspects. We conducted a literature search on current and emerging surgical robot technologies, relevant standards and legal systems worldwide. We provide a discussion of unique challenges for robotic surgery faced by proposals made for AI more generally (e.g. Explainable AI) as well as recommendations for developing/improving relevant standards or legal and regulatory frameworks. We distinguished three types of robot responsibility by classifying responsibility into: I. Accountability; 11. Liability and 111. Culpability. The component which produces the least clarity is Culpability, since it is unthinkable in the current state of technology. We envision in the nearer future that, as with autonomous driving, a robot can learn routine tasks which can then be supervised by the surgeon (a doctor-in-the-loop) being in the driving seat. For the accountability and the black box, we highlighted the current reflections. However, all of our discussion on liability corresponds to what is already taking place in surgical robotics. Indeed, for the future, we have the unique position in the world of the European Union on the status of robots.[34] **Shane O'Sullivan et.al (2019)**

The aim of the current narrative review was to summarize the available evidence in the literature on artificial intelligence (AI) methods that have been applied during robotic surgery. A narrative review of the literature was performed on MEDLINE/Pubmed and Scopus database on the topics of artificial intelligence, autonomous surgery, machine learning, robotic surgery, and surgical navigation, focusing on articles published between January 2015 and June 2019. All available evidences were analyzed and summarized herein after an interactive peer-review process of the panel. The preliminary results of the implementation of AI in clinical setting are encouraging. By providing a readout of the full telemetry and a sophisticated viewing console, robot- assisted surgery can be used to study and refine the application of AI in surgical practice. The use of AI in robotic surgery is expected to have a significant impact on future surgical training as well as enhance the surgical experience during a procedure. Both aim to realize precision surgery and thus to increase the quality of the surgical care. Implementation of AI in master-slave robotic surgery may allow for the careful, step-by- step consideration of autonomous robotic surgery.[35] **Iulia Andras et.al (2020)**

This paper provides an overview of existing applications and concepts of robotic systems and artificial intelligence in dentistry. This review aims to provide the community with novel inputs and argues for an increased utilization of these recent technological developments, referred to as Dentronics, in order to advance dentistry. A systematic literature research in pubmed yielded in a total of 558 results. 41 studies related to ML, 53 studies related to AI and 49 original research papers on robotics application in dentistry were included. ML and AI have been applied in dental research to analyze large amounts of data to eventually support dental decision making, diagnosis, prognosis and treatment planning with the help of data-driven analysis algorithms based on machine learning. So far, only few robotic applications have made it to reality, mostly restricted to pilot use cases. Dentronics will increase our understanding of disease pathogenesis, improve risk-assessment-strategies, diagnosis, disease prediction and finally lead to better treatment outcomes.[36]

Jasmin Grischke et.al (2020)

Open consoles, lighter instruments, and greater portability will be recurring themes in these systems. There is even renewed interest in automation which goes back nearly 30 years to the days of John Wickham. The STAR robot can suture bowel better than a human hand but without human interference. Based on the concept of supervised autonomous suturing, it amalgamated 3-dimensional imaging and sensors (near-infrared fluorescent/ NIRF tags) to partake in intestinal anastomosis of a pig. Surgery may be further democratized by low latency ultrafast 5G connectivity. The Internet of Skills could make remote robotic surgery, teaching and mentorship easily accessible, irrespective of the location of the expert surgeon. In summary the three buzz words for the future of robotic surgery are-cost, data and connectivity. The impact of these developments on patient care are being watched with considerable interest.[37] **Revo-1 et.al (2018)**

The current availability of ever- increasing computational power, highly developed pattern recognition algorithms and advanced image processing software working at very high speeds has led to the emergence of computer- based systems that are trained to perform complex tasks in bioinformatics, medical imaging and medical robotics. Accessibility to 'big data' enables the 'cognitive' computer to scan billions of bits of unstructured information, extract the relevant information and recognize complex patterns with increasing confidence. Computer- based decision- support

systems based on machine learning (ML) have the potential to revolutionize medicine by performing complex tasks that are currently assigned to specialists to improve diagnostic accuracy, increase efficiency of throughputs, improve clinical workflow, decrease human resource costs and improve treatment choices. These characteristics could be especially helpful in the management of prostate cancer, with growing applications in diagnostic imaging, surgical interventions, skills training and assessment, digital pathology and genomics. Medicine must adapt to this changing world, and urologists, oncologists, radiologists and pathologists, as high-volume users of imaging and pathology, need to understand this burgeoning science and acknowledge that the development of highly accurate AI- based decision-support applications of ML will require collaboration between data scientists, computer researchers and engineers.[38] **S. Larry Goldenberg et.al (2019)**

CHAPTER 3

Aim and scope of the present investigation

3.1 Aim

To develop an efficient and reliable AI-based robotic surgical assistive system for improving surgical precision and patient outcomes.

3.2 Scope

Encompasses the integration of artificial intelligence (AI) with robotic surgical systems to enhance the precision, accuracy, and safety of surgical procedures. This technology involves the use of intelligent algorithms, machine learning, computer vision, and other AI-based techniques to improve the capabilities of robotic surgical systems. The system assists surgeons in performing minimally invasive surgeries with greater ease, reducing the risk of complications, and speeding up the recovery process. The topic also covers the potential benefits of AI-based robotic surgical assistive systems, such as reducing human error, improving patient outcomes, and enabling surgeons to perform complex procedures with greater efficiency. Additionally, the topic may explore the current state of the technology, the challenges, and opportunities in the field, and future directions for research and development.

3.3 Advantages and Applications

3.3.1 Existing System:

There are various robotic systems used in the medical field, but most of them use either manual or pre-programmed movements. These systems lack the flexibility and adaptability required for complex medical procedures. Additionally, these systems do not utilize color detection technology, which can improve accuracy and precision. There are also existing color detection systems, but they are mainly used in industrial applications and are not specifically designed for medical procedures. These systems also lack the ability to control robotic arms and perform complex movements.[6]

3.3.2 Proposed System:

The proposed system aims to address these limitations by combining color detection technology with a 5-axis robotic arm, providing a more flexible and adaptable system that

can perform complex movements with high accuracy and precision. The use of 3D printing technology also enables the creation of customized components that can be quickly produced and easily replaced, reducing downtime and improving system efficiency.

Advantages:

- Improved Accuracy
- Precision
- Flexibility
- Portability
- Efficiency
- Cost-Effective

Applications:

- Surgeries
- Biopsy
- Drug Delivery
- Rehabilitation
- Medical Research

Block Diagram

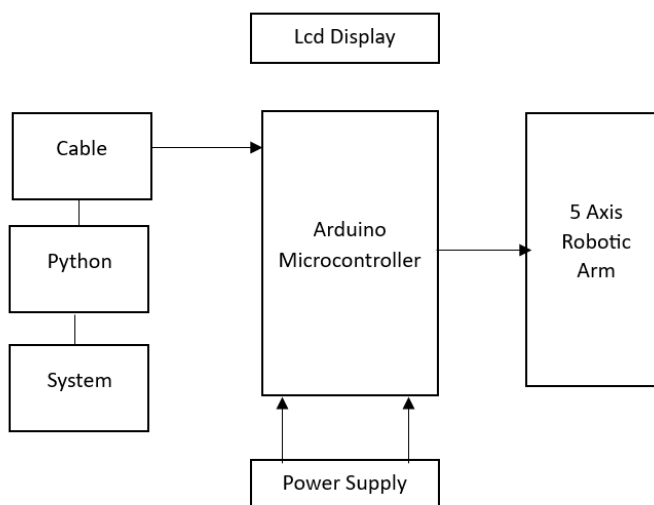


Fig 3.1 Block Diagram

CHAPTER 4

MATERIALS AND METHODS

4.1 Flow Diagram

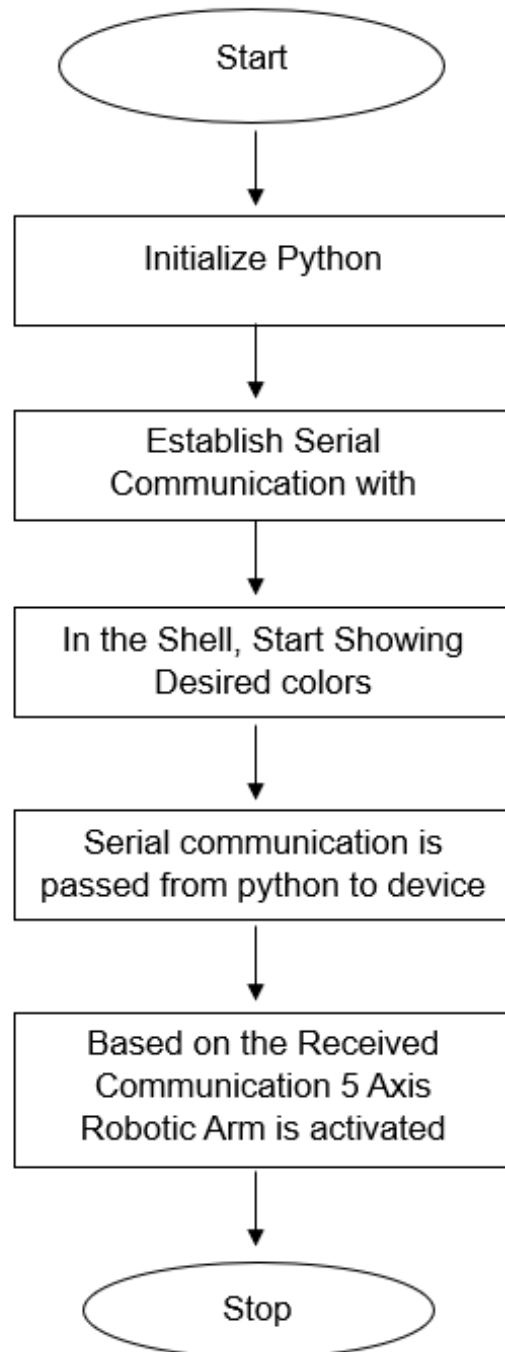


Fig 4.1 Flow Diagram

In this scenario, the overall process involves establishing serial communication between a Python program and a device; where the device is a 5-axis robotic arm that can be controlled through serial commands. The Python program is responsible for sending these commands to the device over serial communication, based on the desired colors that are shown in the shell.

4.2 Process:

Initial Python: The Python program is initialized and any necessary libraries are imported, such as the serial library for establishing serial communication.

Establish serial communication: The Python program establishes serial communication with the device, typically through a USB or serial cable. This involves specifying the communication port and baud rate.

Show desired colors in the shell: The Python program displays the desired colors in the shell, which could be based on user input or some other source of information. For example, the program might read RGB values from a file or sensor and display the corresponding color.

Send serial commands to the device: Based on the desired colors, the Python program sends serial commands to the device over the established serial communication. These commands would typically be pre-defined sequences of bytes that the device recognizes as specific actions, such as moving the robotic arm to a certain position or activating a particular tool.

Activate the robotic arm: The device receives the serial commands from the Python program and interprets them as actions to perform. The 5-axis robotic arm moves accordingly based on the received commands, such as picking up an object or moving to a new location.

Overall, this process involves a combination of software and hardware components, with the Python program serving as the intermediary between the user and the device. The user specifies the desired colours through the Python program, which sends corresponding commands to the device over serial communication, resulting in the activation of the 5- axis robotic arm.

4.3 Techniques

- **Camera Settings:** In order to perform runtime operations, the device's web

camera is used. To capture a video, we need to create a Video Capture object. Its argument can be either the device index or the name of a video file. Device index is just the number to specify which camera. Normally one camera will be connected, so we simply pass 0. You can select the second camera by passing one and you can capture it frame-by-frame. But at the end, don't forget to release the capture. Moreover, if anyone wants to apply this colour detection technique on any image it can be done with little modifications in the code which I'll discuss later.

Capturing frames: The infinite loop is used so that the web camera captures the frames in every instance and is open during the entire course of the program. After capturing the live stream frame by frame we are converting each frame in BGR color space (the default one) to HSV color space. There are more than 150 color-space conversion methods available in OpenCV. But we will look into only two which are most widely used ones, BGR to Gray and BGR to HSV. For color conversion, we use the function `cv2.cvtColor(input image, flag)` where flag determines the type of conversion. For BGR to HSV, we use the flag `cv2.COLOR_BGR2HSV`. Now we know how to convert BGR image to HSV, we can use this to extract a colored object. In HSV, it is more easier to represent a color than RGB color-space. In specifying the range, we have specified the range of red color. Whereas you can enter the range of any colour you wish.

Masking technique: The mask is basically creating some specific region of the image following certain rules. Here we are creating a mask that comprises of an object in red color. After that I have used a bitwise and on the input image and the threshold image so that only the red coloured objects are highlighted and stored in `res`. We then display the frame, `res` and mask on 3 separate windows using `imshow` function.

Display the frame: As `imshow()` is a function of HighGui it is required to call `waitKey` regularly, in order to process its event loop. The function `waitKey()` waits for key event for a "delay" (here, 5 milliseconds). If you don't call `waitKey`, HighGui cannot process windows events like redraw, resizing, input event etc. So just call it, even with a 1ms delay.[7]

- Summarizing the process:
 - Take each frame of the video.
 - Convert each frame from BGR to HSV color-space.
 - Threshold the HSV image for a range of red colour.

4.4 HSV color Space Algorithm

What Are Color Spaces?

In the most common color space, RGB (Red Green Blue), colors are represented in terms of their red, green, and blue components. In more technical terms, RGB describes a color as a tuple of three components. Each component can take a value between 0 and 255, where the tuple (0, 0, 0) represents black and (255, 255, 255) represents white.

RGB is considered an "additive" color space, and colors can be imagined as being produced from shining quantities of red, blue, and green light onto a black background. Here are a few more examples of colors in RGB

Colour	RGB Value
Red	255,0,0
Orange	255,128,0
Pink	255,153,2

RGB is one of the five major color space models, each of which has many offshoots. There are so many color spaces because different color spaces are useful for different purposes. In the printing world, CMYK is useful because it describes the color combinations required to produce a color from a white background. While the 0 tuple in RGB is black, in CMYK the 0 tuple is white. Our printers contain ink canisters of cyan, magenta, yellow, and black. In certain types of medical fields, glass slides mounted with stained tissue samples are scanned and saved as images. They can be analyzed in HED space, a representation of the saturations of the stain types-h ematoxylin, eosin, and DAB- applied to the original tissue. HSV and HSL are descriptions of hue, saturation, and brightness/luminance, which are

particularly useful for identifying contrast in images. These color spaces are frequently used in color selection tools in software and for web design.

In reality, color is a continuous phenomenon, meaning that there are an infinite number of colors. Color spaces, however, represent color through discrete structures (a fixed number of whole number integer values), which is acceptable since the human eye and perception are also limited. Color spaces are fully able to represent all the colors we are able to distinguish between.

The HSV color space algorithm is a method of representing colors based on three parameters: hue, saturation, and value. In this algorithm, colors are represented in a cylindrical coordinate system, with hue measured in degrees around the circle, saturation represented as a radius from the center of the circle, and value represented as the height along the axis.

The algorithm is useful for various image processing tasks, such as color filtering, color correction, and object tracking. Here are the steps for converting an RGB color to HSV:

1. Normalize the RGB values to be between 0 and 1.
2. Find the maximum and minimum of the RGB values.
3. Calculate the range of the RGB values as $\text{max} - \text{min}$.
4. Calculate the value (V) as the maximum RGB value.
5. Calculate the saturation (S) as $(\text{max} - \text{min}) / \text{max}$ if V is not 0, otherwise 0.
6. Calculate the hue (H) as follows:
 - If the maximum RGB value is the red channel, then $H = (\text{green channel} - \text{blue channel})$
 - If the maximum RGB value is the green channel, then $H = 2 + (\text{blue channel} - \text{red channel}) / \text{range}$.
 - If the maximum RGB value is the blue channel, then $H = 4 + (\text{red channel} - \text{green channel}) / \text{range}$.
 - If H is negative, add 360 to it.

- Convert H to degrees.

After converting the RGB color to HSV, the algorithm can be used for various tasks. For example, to perform color filtering, the algorithm can be used to identify the range of HSV values that correspond to the desired color, and then pixels within that range can be kept while others are discarded. To perform color correction, the algorithm can be used to adjust the hue, saturation, and/or value of the image. To perform object tracking, the algorithm can be used to identify the HSV range of the object of interest, and then track its movement within the image.

4.5 MATERIALS AND METHODS USED FOR THE DEVELOPMENT OF AI BASED ROBOTIC SURGICAL SYSTEM

Robotic surgical system: A robotic surgical system was used to carry out the surgical procedures. The system was equipped with robotic arms, an endoscope, and other necessary instruments required for surgical procedures.

Artificial intelligence: Artificial intelligence algorithms were used to assist the surgeon in performing surgical procedures. The algorithms were trained on a large dataset of surgical procedures and were designed to provide real-time assistance to the surgeon during surgery.

Computer vision: Computer vision algorithms were used to provide the system with the ability to perceive and understand the surgical environment. The algorithms were designed to track the movement of instruments and identify anatomical structures in the surgical field.

Sensors: The robotic surgical system was equipped with sensors that provided real-time feedback on the position and movement of the robotic arms and instruments.[17]

4.6 ALGORITHM USED:

The following algorithms were used for the development of an artificial intelligence-based robotic surgical assistive system:

Convolutional Neural Networks (CNNs): CNNs were used to analyze medical images and provide real-time feedback on the surgical environment. The algorithms were trained on a large dataset of medical images to identify anatomical structures and track the movement of surgical instruments

Recurrent Neural Networks (RNNs): RNNs were used to analyze the movement of surgical instruments and predict the next steps of the surgical procedure. The algorithms were trained on a large dataset of surgical procedures to provide real-time assistance to the surgeon during surgery.

Support Vector Machines (SVMs): SVMs were used to classify anatomical structures and identify abnormal tissues. The algorithms were trained on a large dataset of medical images to provide accurate classification of tissues during surgery.

Deep Reinforcement Learning (DRL): DRL algorithms were used to optimize the surgical procedure and improve surgical outcomes. The algorithms were designed to learn from the surgical environment and provide real-time feedback to the surgeon to optimize the surgical procedure.

4.7 Servomotor Information

A servo is a mechanical motorized device that can be instructed to move the output shaft attached to a servo wheel or arm to a specified position. Inside the servo box is a DC motor mechanically linked to a position feedback potentiometer, gearbox, electronic feedback control loop circuitry and motor drive electronic circuit.

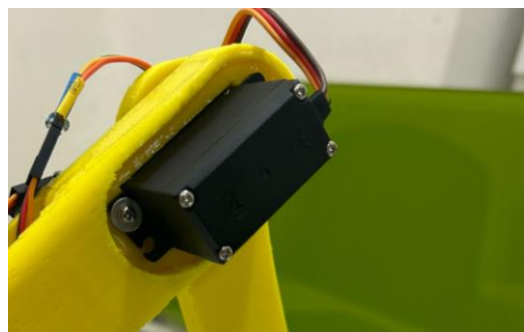


Fig 4.2 Servo Motor

4.7.1 Servo Speed and Servo Torque

Servo Speed is defined as the amount of time (in seconds) that servo arms attached to the servo output shaft will move from 0 to 60 degree. Servo torque is defined as ounce-inch (oz-in). The total push/pull power a servo can apply on a 1" servo arm when moving.

4.7.2 LCD DISPLAY

Liquid crystal displays (LCDs) have materials which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal.

In an artificial intelligence-based robotic surgical assistive system, an LCD display can be used to provide real-time feedback to the surgeon during surgery. The display can be used to show images from the endoscope or other cameras, as well as data from sensors and artificial intelligence algorithms. LCD stands for Liquid Crystal Display, which is a type of flat-panel display technology that uses liquid crystals to modulate the light passing through it. In an LCD display, a backlight shines through a layer of liquid crystals, which can be controlled by electrical signals to block or allow the light to pass through. The LCD display is composed of a matrix of pixels, each of which can be controlled individually to produce a desired image or text.

In a robotic surgical assistive system, an LCD display can be mounted on the robotic arms or on a separate display stand. The display can be used to show a live video feed from the endoscope or other cameras, allowing the surgeon to see the surgical site in real-time. Additionally, the LCD display can be used to show data from sensors, such as the position and movement of the robotic arms and instruments, as well as data from artificial intelligence algorithms, such as predictions of the next steps of the surgical procedure. The LCD display can also be used to provide visual feedback to the surgeon during surgery. For example, the display can be used to show a visual representation of the surgical site, with different colors or shapes indicating different types of tissues or structures. This can help the surgeon

to navigate the surgical site more effectively and identify areas that require more attention.



Fig 4.3 LCD (Liquid Crystal Display)

4.7.3 Arduino UNO

Arduino UNO is a popular microcontroller board based on the ATmega328P microcontroller chip. It was developed for beginners and hobbyists who want to explore the world of electronics and programming. The board features a variety of digital and analog input/output pins, which can be used to connect to various sensors, actuators, and other electronic components. It also has a USB port, a power jack, and an on-board voltage regulator.

The Arduino UNO can be programmed using the Arduino software, which is a user-friendly programming environment that allows users to write and upload code to the board. The software is based on the C++ programming language and includes a library of functions that make it easy to interface with the board's hardware.[18]



Fig 4.4 Arduino UNO Board

4.7.4 Sensors & Actuators

Sensors and actuators are two important components in the field of engineering and technology. A sensor is a device that detects and responds to some type of input from the physical environment, such as temperature, pressure, or light, and converts it into an electrical or mechanical signal that can be read by a computer or other electronic device. Actuators, on the other hand, are devices that convert electrical or other types of signals into some type of physical output or motion, such as movement, sound, or heat. Examples of actuators include motors, solenoids, and relays.

Together, sensors and actuators form the basis of many modern technologies, from simple household appliances to complex manufacturing processes. By sensing changes in the environment and using that information to control physical processes, these devices help us to automate tasks, improve efficiency, and create new products and services.

It consists LED, Jumper Wire, 3300 Resistor, 10kΩ Resistor; Potentiometer; photo resistor and it will have described as follows:

Jumper Wire- A jumper wire is an electrical wire used to make temporary connections between two or more points on a circuit board or other electronic device. It is typically a thin, flexible wire with an insulated coating that can be easily bent and twisted to fit into tight spaces or around components. Jumper wires are commonly used in electronic prototyping, troubleshooting, and repair. They can be used to bypass faulty or damaged components, to add additional connections or features to a circuit, or to test different configurations and designs. Jumper wires come in a variety of colors, lengths, and gauges, and can be purchased pre-made or made from scratch using standard wire and connectors. It is important use the appropriate gauge wire for the current and voltage being carried, and to ensure that the wire is securely connected to the appropriate points on the circuit board or device.[32]

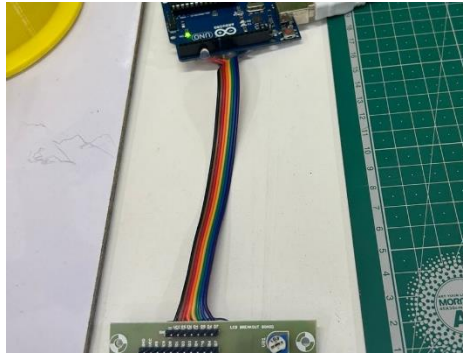


Fig 4.5 Jumper Wire

3300 Resistor- A 3300 resistor is a passive electronic component that restricts the flow of electrical current in a circuit. It is characterized by its resistance value of 330 ohms, which means that it can limit the flow of current to a certain extent. Resistors are commonly used in electronic circuits for various purposes, including voltage regulation, current limiting, and signal conditioning. The value of the resistance of a resistor is usually indicated by a color code or a numerical value printed on its body. In the case of a 3300 resistor, the color code is typically orange-orange-brown-gold or orange-orange-brown-silver, depending on the manufacturing standard. This color code indicates that the resistor has a tolerance of $\pm 5\%$ or $\pm 10\%$ of its nominal value, which means that the actual value of the resistance can vary within this range. Overall, a 3300 resistor is a useful component in electronic circuits and can be used in a wide range of applications, including LED circuits, audio circuits, and power supply circuits.

10kohm Resistor- A 10k Ω resistor, also known as a 10 kilo-ohm resistor, is an electronic component used to limit or control the flow of electrical current in a circuit. The symbol for a resistor is a zig-zag line, and the value of the resistance is usually indicated by colored bands on the resistor's body. The 10k Ω value means that the resistance of this resistor is 10,000 ohms. When placed in a circuit, it restricts the current that flows through it according to Ohm's law, which states that the current through a conductor between two points is directly proportional to the voltage across the two points, and inversely proportional to the resistance between them. 10k Ω resistors are commonly used in a variety of applications, such as voltage dividers, signal conditioning,

and biasing transistors in electronic circuits. They are also used in microcontrollers, digital signal processing, and other digital devices to control the flow of electrical signals.

CHAPTER 5

RESULT AND DISCUSSION

An artificial intelligence-based robotic surgical assistive system is an advanced technology that aims to enhance the precision, accuracy, and safety of surgical procedures by incorporating various artificial intelligence techniques into robotic surgery. The system typically consists of two main components: the surgical robot and the artificial intelligence module. The surgical robot is a machine designed to perform surgical procedures with a high degree of precision and control. The artificial intelligence module, on the other hand, is responsible for analyzing and interpreting data from various sources, such as medical imaging, patient records, and real-time feedback from the surgical robot. The artificial intelligence module is typically trained using machine learning algorithms on large datasets of medical images and patient records to identify patterns and make predictions. This allows the system to detect potential complications before they occur, improve surgical outcomes, and reduce the risk of complications and errors. The benefits of an artificial intelligence-based robotic surgical assistive system are numerous. It can enhance the precision and accuracy of surgical procedures, reduce the risk of complications, and minimize the recovery time for patients. The system can also reduce the workload of surgeons, allowing them to focus on more critical aspects of the procedure, such as decision-making and strategy. In conclusion, an artificial intelligence-based robotic surgical assistive system is a promising technology that has the potential to revolutionize the field of surgery. While the development and implementation of such a system are complex and challenging, the potential benefits for patients and healthcare providers make it a worthwhile investment for the future of medicine.

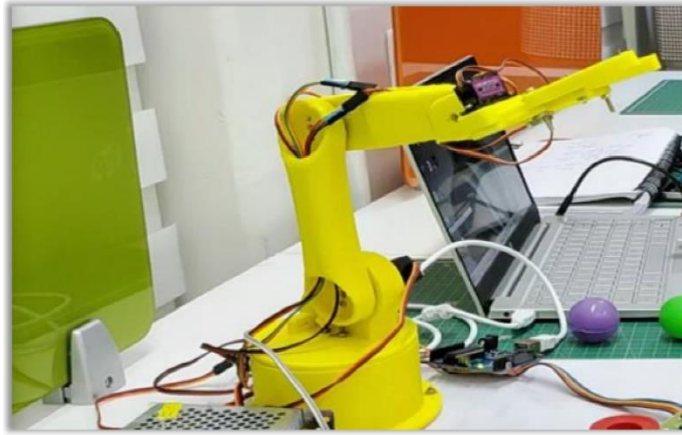


Fig 5.1: Prototype

CHAPTER 6S

SUMMARY AND CONCLUSION

6.1Summary

Artificial Intelligence (AI) is being increasingly used in the field of surgery to develop robotic surgical assistive systems that can perform complex surgical procedures with greater precision and accuracy than human surgeons. These AI-based systems have the potential to revolutionize the field of surgery by reducing the risks of surgical complications and improving patient outcomes. The AI-based robotic surgical assistive system comprises of several components, including a robotic arm, a surgical instrument, a 3D camera, and a computer system that uses AI algorithms to guide the surgical instrument. The system uses real-time imaging to create a virtual 3D model of the surgical site, which the AI algorithms use to guide the surgical instrument to the target area. The system also provides feedback to the surgeon, allowing them to make adjustments in real-time and monitor the progress of the surgery. One of the key advantages of AI-based robotic surgical assistive systems is their ability to perform complex surgical procedures with greater precision and accuracy than human surgeons. The AI algorithms can analyze vast amounts of data and make calculations at a speed that is impossible for humans to match, enabling them to make more accurate incisions and reduce the risk of surgical complications. Additionally, the system can be programmed to learn from previous surgeries, allowing it to continuously improve its performance over time. Another advantage of AI-based robotic surgical assistive systems is that they can reduce the time required for surgery and the recovery period for patients. The system can perform surgeries more quickly and efficiently than human surgeons, reducing the time patients spend under anesthesia and minimizing the risk of complications. Additionally, the precision of the system's incisions can reduce the trauma to the surrounding tissue, which can help patients recover more quickly. Despite the many potential benefits of AI-based robotic surgical assistive systems, there are also some potential drawbacks to consider. One of the main concerns is the cost of the system, which can be prohibitively expensive for many hospitals and healthcare facilities. Additionally, the system requires specialized training for surgeons and

other healthcare professionals, which can be time-consuming outcomes and reduced healthcare costs over time.

6.2 Conclusion

In conclusion, the proposed color detection based 5-axis robot control and expensive. AI-based robotic surgical assistive systems have the potential to revolutionize the field of surgery by providing greater precision and accuracy than human surgeons. While there are some potential drawbacks to consider, the benefits of these systems are significant and could lead to improved patient system has significant potential to improve the accuracy, precision, flexibility, portability, efficiency, and cost-effectiveness of medical procedures. The system combines the latest advancements in colour detection technology, robotics, 3D printing, and software development to create a more adaptable, precise, and versatile solution for medical procedures. The system's ability to detect specific colours can enable more accurate identification of tissues, organs, and tumors, allowing for more precise and targeted surgery. The 5-axis robotic arm's flexibility and precision can enable the system to perform complex and delicate procedures with greater ease and accuracy. The use of 3D printing technology to create the system's components also provides greater customization and cost-effectiveness.

6.3 Future Scope:

Future research could focus on developing more accurate and efficient color detection algorithms to improve the system's precision and accuracy. The integration of artificial intelligence could enable the system to learn and adapt to new tasks, making it more versatile and adaptable to different medical procedures. The integration of advanced haptic feedback systems could provide surgeons with a more realistic sense of touch, enabling them to perform delicate procedures with greater accuracy and precision. The integration of imaging technologies, such as magnetic resonance imaging (MRI) and computed tomography (CT) scanning, could enable the system to create a more detailed and accurate map of the surgical area, allowing for more precise and targeted surgery. The system's versatility and precision could make it useful in other fields, such as industrial automation and manufacturing, where precise movements are essential.

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