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ROBOTIC INTERFACE CONTROLLER FOR MINIMALLY INVASIVE SURGERY

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Abstract-Recent technological advances in surgery have resulted in the development of a range of new techniques that have reduced patient trauma, shortened hospitalization, and improved diagnostic accuracy and therapeutic outcome. Despite the many appreciated benefits of minimally invasive surgery (MIS) compared to traditional approaches, there are still significant drawbacks associated with conventional MIS including poor instrument control and ergonomics caused by rigid instrumentation and its associated fulcrum effect. The use of robot assistance has helped to realize the full potential of MIS with improved consistency, safety and accuracy. The development of articulated, precision tools to enhance the surgeon's dexterity has evolved in parallel with advances in imaging and human– robot interaction. This has improved hand-eye coordination and manual precision down to micron scales, with the capability of navigating through complex anatomical pathways. Allied technical approaches and engineering challenges related to instrument design, intraoperative guidance, and intelligent human–robot interaction are reviewed. We also highlight emerging designs and research opportunities in the field by assessing the current limitations and open technical challenges for the wider clinical uptake of robotic platforms in MIS.
Index Terms—Human–robot interaction, image- guided surgery, minimally invasive surgery, surgical robots.

INTRODUCTION

The field of surgery is under constant evolution. Surgeons continue to explore new approaches to improve outcomes for patients by making procedures safer and more effective.

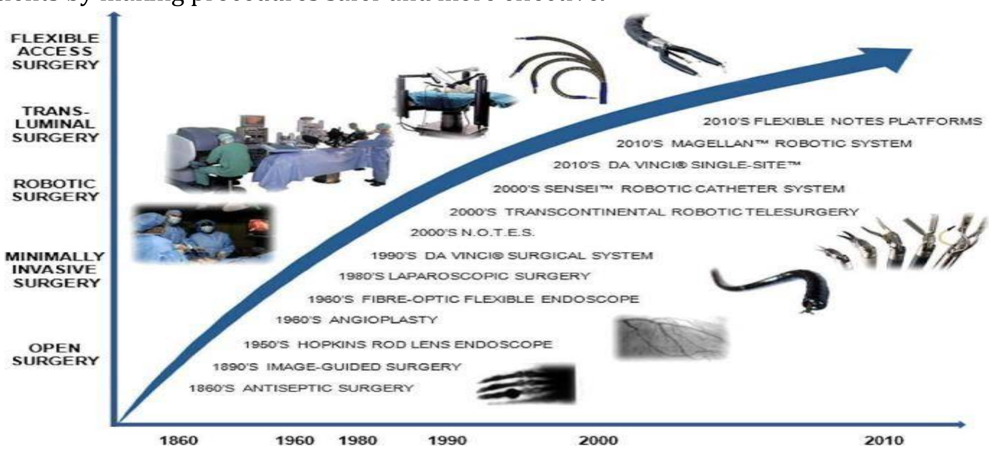

Fig.1.1-Some of the key milestones in minimally invasive surgery, image guidance and surgical technology

This pursuit has been ongoing for many generations, with early breakthroughs occurring in the 1860s with Lister's seminal work on antiseptic surgery. Alongside these endeavours, advances in technology have played crucial roles in aiding, as well as enhancing, the abilities of surgeons to refine, or redefine, their specialities. In the days of the barber-surgeon, the practice of surgery was more of a purely technical craft. Modern surgery is now strengthened by technologies. Remarkable successes in diagnostic and therapeutic strategies within these fields will undoubtedly continue to transform the management of surgical illness and disease. However, at the core of surgical practice will remain the emphasis on technical rigor and performance. Today's challenge is to develop technology that meets the demands of flexible access surgery. Not surprisingly, attempted application of existing mechanically operated flexible endoscopes, designed exclusively for intraluminal use, has proven largely unsuitable. Specialized instrumentation with enhanced, integrated flexibility, stability and dexterity to reach the operative target sites through complex anatomical pathways is required.

WORKING OF ROBOTIC ARM

This paper provides an overview of the emerging robotic platforms for MIS, developed in response to the clinical interest and uptake of flexible access surgery. The paper is mainly focused on design approaches and hardware considerations of flexible access surgery, particularly for the integration of effective human–robot interaction. An introduction to the access routes for MIS and the technical challenges associated with each is first presented in Section II. Section III describes the emerging robotic platforms, categorized into their engineering design, as well as the state of the art in human–robot interaction. Imaging and navigation techniques are briefly presented in Section IV, in order to provide an overall picture of robotic system requirements for MIS. Finally, in Section V, we describe the limitations and technical challenges for safer and wider integration of robotic systems across surgical disciplines for MIS.

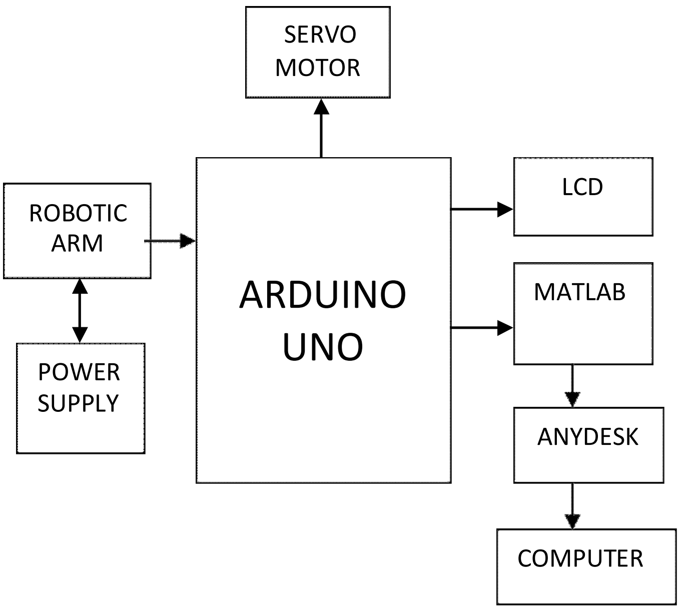

Fig.2.1- Block Diagram

SCHEMATIC LAYOUT OF THE SYSTEM

The schematic layout of the system is shown in Fig. 3 and Fig. 4 shows the experimental setup. In robotic surgery, the exploitation of synergistic integration of machine precision and human control overcomes many of the issues related to traditional MIS. The fulcrum effect is eliminated by using the digital, rather than mechanical, master–slave setup. At the same time, precise motion control of the instrument tip is achieved by tremor removal and motion scaling. Wrist articulation is introduced by additional flexibility at the slave level. Recent advances in imaging and digital vision technologies such as high definition stereoscopic displays with augmented reality have further enhanced the capabilities of the surgeon's console. The integration of current robotic technologies into clinical practice has enabled further minimization of skin incisions by single-incision and natural orifice access routes, combined with MIS approaches to more complex procedures. The main requirement for such endeavours is the ability to adequately access different target anatomy from access sites that are not aligned in the most direct and ergonomically optimum positions. The term flexible access surgery most appropriately characterizes these novel techniques for the next evolutionary phase of MIS. Today's challenge is to develop technology that meets the demands of flexible access surgery.

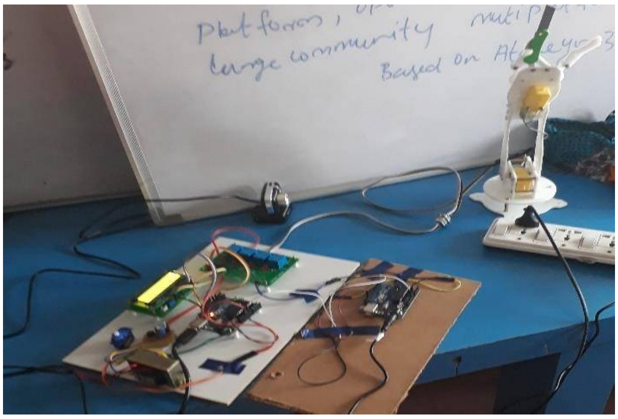

Fig.3.1-Schematic Layout

RESULT AND DISCUSSION

For intraoperative navigation, the use of pre- and intra-operative imaging for surgical guidance is now common. Nonetheless, the consolidation of methods for non rigid registration and tracking of tissue deformation in real time coupled with advances in augmented reality techniques will ensure a better synthesis of preoperative and intraoperative data for navigation. Dynamic modelling of the tissue will also allow for the implementation of active constraint control in a surgical environment. Finally, internal instrument channels within flexible robotic platforms can broaden the possibilities of real-time optical biopsy and cellular level imaging for superior pathology localization and treatment strategies. It is anticipated that the realization of these research goals will lead to the development of enhanced flexible robots, enabling greater clinical uptake. Focusing on improved patient satisfaction and outcomes, coupled with superior ergonomics and control for the surgeon, robot- assisted flexible access surgery can take MIS into a new era in the near future.

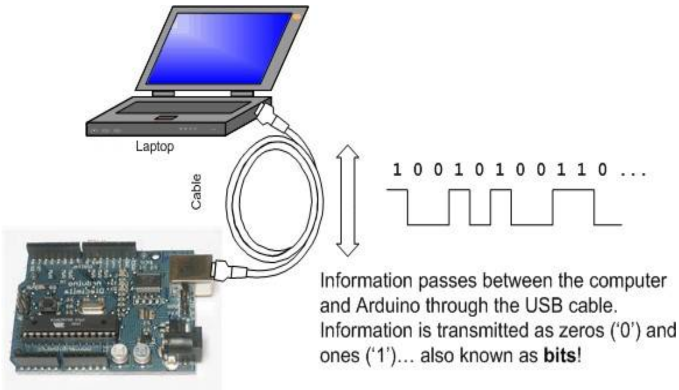

Fig.4.1- Serial communication of Arduino and computer.

Future medical robotics research should focus on the design of lightweight flexible manipulators with minimum footprint in the operative theater and ergonomic interfaces that can simplify or alleviate the surgeon's cognitive burden. Such surgical robots are likely to be intrinsically complex and intelligent, yet simple, lightweight. They should enhance the current surgical work-flow, rather than alter it completely or become a hindrance to the normal procedures. In this regard, improved mechatronic design, advanced imaging and integrated sensing are vital to the development of the next generation of flexible robotic systems. This will also help to reduce the physical separation and move the surgeon back to the operating table, leading to truly robotically assisted, rather than robotically dominated, surgical procedures.

CONCLUSION

Surgery is an evolving discipline, benefitting from rapid technological advances and driven by our ongoing pursuit for early intervention and minimally invasive therapy. Traditional laparoscopic tools have limited surgical performance for procedures involving complex anatomical pathways between the access route, entry point and operative sites. It is evident from this review that flexible robotic platforms have yet to reach their maturity with further technological and engineering advances. While gains in flexibility and system con-trol have been made, the focus on cost and footprint reduction may be addressed by efforts to achieve components miniaturization. The impairments of physical and perceptual separation.

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