Indian Institute of Technology Delhi

School of Interdisciplinary Research (SIRe)

SIRe Project Number

2025-01-29

(will be assigned by SIRe)

Project Proposal for Ph.D.

Project Details (The research problem must clearly indicate the need for an interdisciplinary approach)	
Project Title	Wireless-Enabled Surgical Workflows in Minimally Invasive Surgery: Improving Efficiency and Reducing Surgeon Fatigue
Project Summary (Minimum 500 and maximum 2000 characters)	Minimally Invasive Surgery (MIS) has revolutionized modern medicine by reducing patient trauma, accelerating recovery times, and lowering post-operative complications. Despite these advancements, current MIS techniques are hindered by the reliance on wired systems for endoscopic imaging, robotic-assisted tools, and intraoperative monitoring. The extensive use of wired connections introduces significant limitations, including restricted surgeon mobility, increased physical strain, operating room clutter, and complex sterilization requirements. These challenges highlight a crucial knowledge gap in the integration of wireless technologies within MIS to enhance surgical precision, workflow efficiency, and ergonomic design. The shift to wireless-enabled surgical systems offers a transformative solution to these issues. By eliminating the physical constraints of wired connections, surgeons can operate with greater freedom of movement, reducing fatigue and enhancing precision in long-duration procedures. The removal of cables from the sterile field also simplifies infection control measures, minimizing contamination risks and improving sterilization protocols. Moreover, a wireless setup creates a more organized and efficient operating room environment, allowing surgical teams to focus on procedural execution rather than navigating around cables and wired equipment. A critical component of this transition is the implementation of high-resolution wireless imaging systems. Real-time visualization is the cornerstone of MIS, where the accuracy of intraoperative decisions is highly dependent on high-quality imaging. Traditional wired systems provide stable, high-definition video feeds, but they limit mobility. The adoption of advanced wireless communication technologies, such as 5G, Wi-Fi 6, and ultra-low-latency transmission protocols, ensures seamless and lag-free transmission of high-resolution surgical video. However, achieving the same level of reliability, low latency, and interference resistance as wired systems remains a significant engineering challenge that must be addressed through system design innovations. Beyond imaging, the design of wireless surgical tools must prioritize ergonomics and usability to reduce surgeon fatigue. Wired instruments, especially those used in robotic-assisted surgery, contribute to long-term musculoskeletal strain due to their rigidity and weight. Wireless alternatives, designed with lightweight materials and improved grip mechanics, can enhance hand stability and reduce physical stress. Additionally, removing cables from the equation eliminates the risk of entanglement, allowing surgeons to maintain better posture and focus on precision. A well-designed wireless toolset must balance factors such as weight distribution, haptic feedback, and intuitive control interfaces to ensure a seamless transition from wired systems without compromising surgical accuracy. Sterilization is another crucial aspect that wireless technologies can optimize. Traditional wired surgical instruments require extensive sterilization due to multiple physical contact points, connectors, and cabling. Wireless tools reduce these complexities by eliminating unnecessary direct contact components, leading to streamlined sterilization procedures and lower infection risks. However, wireless components introduce new design considerations, such as ensuring that embedded batteries and electronic circuits can withstand autoclaving or other high-temperature sterilization methods. This necessitates the exploration of alternative sterilization techniques, including disposable covers, UV-C sterilization, and biocompatible antimicrobial coatings for reusable wireless instruments. Despite the clear advantages, the transition to wireless-enabled MIS presents several engineering and implementation challenges. The primary concern is ensuring the reliability and stability of wireless communication in a high-risk environment where real-time data transmission is critical. Signal interference, latency fluctuations, and potential cybersecurity vulnerabilities must be addressed through robust protocol design and encryption mechanisms. Additionally, power management in wireless surgical instruments remains a challenge, as battery life constraints must be optimized to support extended surgical procedures without requiring frequent recharges or replacements. This research aims to bridge the knowledge gap in wireless surgical technology by evaluating its impact on surgical precision, efficiency, and ergonomics while addressing

	key design challenges. While wireless systems have been successfully implemented in other industries, their application in real-time, high-precision surgical environments remains underdeveloped. There is a pressing need for comprehensive studies assessing the long-term effects of wireless surgical tools on surgeon fatigue, procedural efficiency, and patient safety. Furthermore, this study will explore novel hardware and software design strategies to ensure seamless wireless integration without compromising performance or reliability. The implementation of wireless-enabled MIS will have profound implications for the future of surgery. By reducing clutter in the operating room, enhancing surgeon mobility, and improving workflow efficiency, wireless systems will contribute to shorter procedure times and better patient outcomes. Enhanced ergonomic designs will promote long-term health benefits for surgeons, reducing fatigue-related errors and increasing career longevity. Additionally, improved sterilization methods will lower infection rates, making surgical environments safer and more hygienic. In conclusion, the transition to wireless-enabled minimally invasive surgery represents a critical evolution in modern surgical practice. By addressing the limitations of wired systems and focusing on innovative wireless communication and ergonomic design, this research will contribute to the development of a more efficient, sterile, and surgeon-friendly operating environment. The findings from this study will not only advance surgical technology but also pave the way for the next generation of intelligent, wireless-driven surgical systems that enhance both patient care and surgeon well-being.

Ph.D. Supervisors
(Supervisor 1 and Supervisor 2 cannot be from the same department of IITD)

Role	Name of Faculty	Academic Unit in IITD/Institute/University	Email ID (Official)
Supervisor 1	Jay Dhariwal	Dept. of Design, IIT Delhi	jay@design.iitd.ac.in
Supervisor 2	Dinesh KalyanaSundaram	CBME, IIT Delhi	dineshk@cbme.iitd.ac.in

Project requirements (Student qualifications, experience required, etc)
***The candidate will be shortlisted based on common shortlisting criteria decided by ScRC (SIRe)**

- A Master's degree in Design, Engineering, Sciences or the related fields from a recognized institution.
- The candidate must have expertise in **embedded software and hardware development**, preferably with **at least one year of experience** in designing and developing **medical devices, real-time systems, and wireless communication solutions**. Strong proficiency in **AI, data science, machine learning, and image processing** is desired, along with hands-on experience in **low-latency video transmission, embedded Linux, and ARM-based architectures**. Prior work in **wireless minimally invasive surgical technologies** and **cloud-integrated medical applications** will be an added advantage.

Source of fellowship/funding and project number
(CSIR/UGC/DBT/ICMR/ICAR/NEET-PG/DST-INSPIRE/IRD/FITT Project details, if any)

Project Funding

Role of Faculty Members involved:

Supervisor-1	Guidance on medical device research and development, design and prototyping, ergonomics
Supervisor-2	Guidance on the clinical side workflows including lab testing, clinical trials, research methods