BLADE: Bioimpedance-Enabled Laparoscopic Articulated Dual-Purpose Endowrist System for Force Sensing, Anomaly Detection, and Natural Control in Robotic Surgery

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Robotic-assisted minimally invasive surgery (RAMIS) was used in millions of procedures in 2025. Despite its widespread adoption, current systems largely lack force-sensing capabilities and real-time diagnostic functionality. Recent studies have developed predictive models correlating bioimpedance with applied force to enable simultaneous tissue identification and force estimation; however, these models suffer from high noise levels and lack surgeon-ready interfaces for operating room use. To address these limitations, BLADE was developed as a comprehensive surgical enhancement system that integrates a bioimpedance measurement circuit with Da Vinci S Precise Bipolar Forceps. The system provides tissue-specific force warnings, subsurface anomaly detection, and natural glove-based control. Operating at 5 MHz within the ß-dispersion range, BLADE achieves improved signal quality and demonstrates an exponential relationship between force and impedance. Experimental results show a tissue classification accuracy of 96.17%, representing an 11.18% improvement over prior a-dispersion-based models. A real-time warning framework alerts surgeons when applied force exceeds safe thresholds for sensitive tissues. The anomaly detection algorithm employs a triple-criterion approach—rate-of-change (dZ/dt < -30 kO/s), absolute threshold (Z < 20 kO), and temporal confirmation (200 ms)—to reliably identify subsurface tumor-like masses. Additionally, a glove interface incorporating flex, acceleration, and rotation sensors enables natural, gesture-based control of all Intuitive EndoWrist axes. This low-cost, scalable system represents a significant step toward integrated haptic feedback and intraoperative diagnostics, with the potential to revolutionize robotic surgery and patient outcomes.

Awards Won:

Fourth Award of $600

Zydus Pharmaceuticals USA Inc.: Third Place Biomedical Engineering

Patent and Trademark Office Society: First Award of $500

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