Close-loop control for a wireless Magnetic Actuated Laparoscopic Camera

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Introduction

Single-incision laparoscopic surgery (SILS) allows surgeons to perform surgery by sharing a single incision for instruments and laparoscope, which reduces trauma, scarring, and hospitalization. However, SILS sacrifices laparoscope workspace due to limited space. Besides, handling laparoscope causes extra burden for surgeons. In this work, we integrate a wireless laparoscope with a collaborative manipulator based on magnetic anchoring and guidance system (MAGS). Applying force-position closed-loop control, the robot arm navigates the camera precisely. The system provides large workspace for laparoscope and lays foundation for autonomous surgery.

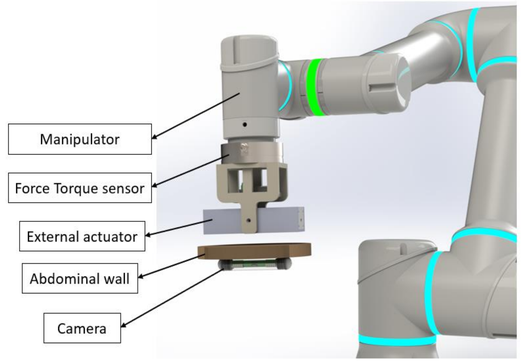


Fig.1 Conceptual illustration of the wireless laparoscope system

Materials and Methods

In Fig.1, the system contains a wireless camera, an external actuator, a force torque sensor and a human-friendly manipulator. The camera and actuator are integrated

magnet pairs, which generates magnetic coupling to anchor and maneuver the camera. The force torque sensor monitors the contact force between the camera and patient tissue to avoid excess pressure. Fig.2 shows the magnetic actuation mechanism. Two internal permanent magnets (IPMs) and external permanent magnets (EPMs) locate at each side of the camera and the actuator. The magnetic force attracts the camera against onto abdominal wall. A micromotor inside the actuator drives the camera to tilt around X_R. Pan and translate motion are controlled by manipulator. The IMU and hall sensor is embedded into the camera to estimate its' pose and position. Combining the measurement of force torque sensor, the force-position control is applied to provide smooth and precise navigation.

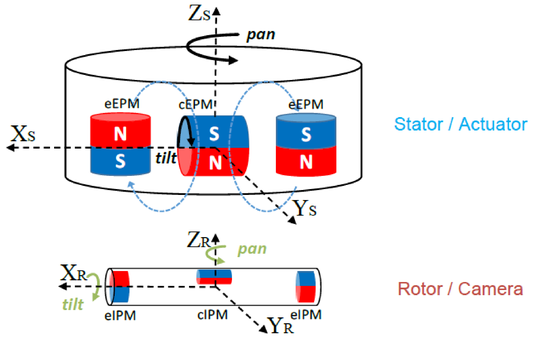


Fig.2 Magnetic actuation mechanism

Results and Discussion

As illustrated in Fig.3, our camera is compact with length of 80mm and diameter of 12mm. The rotor board is built around a Texas Instruments cc2541 Bluetooth MCU. Analog video and digital sensing data are sent out to the PC through an AV transmitter and cc2541 wirelessly. The motor (1016M009SR, FAULHABER) inside actuator integrated with a 256:1 ratio gearhead can generate 1Nm torque which is sufficient to drive the magnets. The setup is shown in Fig.4. Our camera is tested on URe5. The force sensor (ATI-9105-Axia80-M20) communicates with PC through Ethernet. The laparoscopic system is controlled with an operation interface through PC, which can be further developed into autonomous camera guidance system.

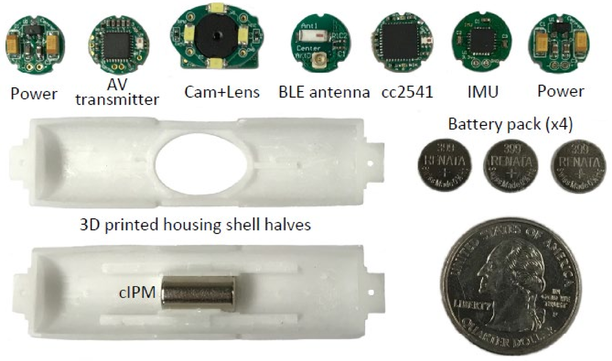


Fig.3. Camera modular

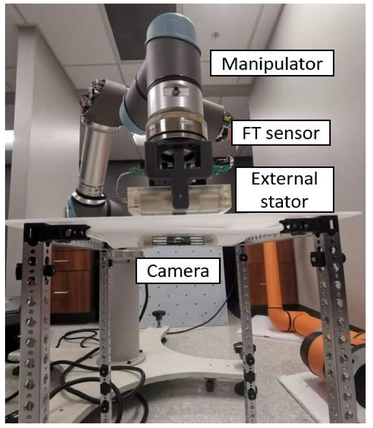


Fig.4. Setup of the system

Conclusion

This work proposed a closed-loop control for a wireless camera system in SILS. The camera is capable of tilting, panning and translating inside patient body, while the power consuming actuation part is left outside the cavity. The experiments showed the position control of the camera navigated by a manipulator is improved. Besides, the force control loop provides motion compensation to constrain the contact force between camera and patient tissue within a safe range. In the future, servo control and self-learning algorithm will be further applied to develop an intelligent assistant.