Developing Wireless Interface Devices for Real-Time Surgical Interaction with Computer Systems During Fluorescence Guided Procedures

Aizhan Moore, Conor Delaney, Dr. Ronan Cahill, Dr. Kevin Nolan
College of Engineering & Architecture, University College Dublin, Belfield, Dublin 4, Ireland
College of Engineering & Computer Science, Syracuse University, Syracuse, NY, USA

Introduction

Fluorescence-guided surgery utilizes indocyanine green (ICG), a fluorescent agent injected into the patient, and specialized cameras to detect visible and near-infrared light. This technique highlights areas of tissue perfusion, aiding surgeons in critical decisions, such as determining the safety of tissue reconnection during colorectal surgeries.

Interpreting ICG fluorescence can be challenging. An artificial intelligence-driven computer system is being developed to analyze fluorescence in real-time and assist with decisions on bowel resection. Trained using videos of decisions made in prior surgeries by experienced surgeons, the A.I. interprets fluorescence patterns to support intraoperative choices.

This study focuses on designing a sterile, wireless, and intuitive hand-held device to enable surgeons to interact with the A.I. during operations. While voice and gesture controls are also under development, this project centers on creating a practical and efficient tool for real-time surgical support.

Voice Method

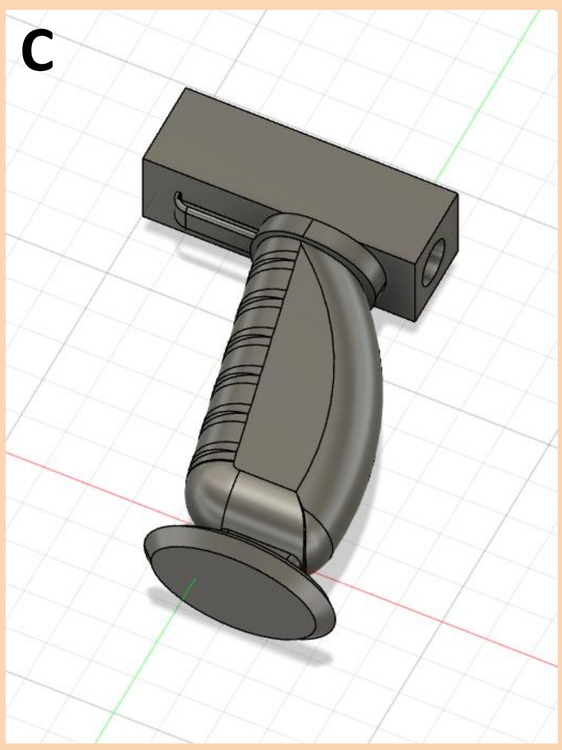
When bowel images are displayed, areas with sufficient blood flow (high ICG fluorescence) are shown. Axes with numerical values (x- and y-coordinates) appear on the screen. To select a region for analysis, the surgeon verbally specifies two points, e.g., “Point (X1, Y1) to point (X2, Y2),” and uses commands like “line” to draw a line for perfusion analysis or “start” to initiate video analysis. The computer system then analyzes the selected region for fluorescence to assess blood supply. Siri and Alexa are consumer examples.

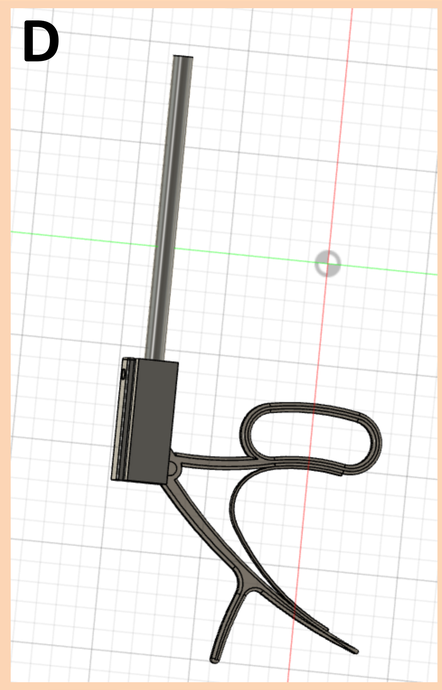
Hand Gesture Method

The hand gesture method uses a camera to track the surgeon’s movements for system interaction. Raising an open hand moves the on-screen cursor, while a closed fist locks it in place. To select points, the surgeon forms a closed fist and raises an index finger, repeating the gesture to mark a second point. The system then analyzes the selected region for fluorescence and blood supply. Microsoft Kinect is a consumer example of this interaction method.

Research Techniques

- Observed colorectal surgeries to study current A.I.-assisted methods for determining optimal bowel resection sites.
- Proposed a third interaction method using a wireless pointer device.
- Verified the functionality of a purchased wireless pointer as a computer mouse.
- Designed and prototyped ergonomic solutions in Autodesk Fusion 360 to improve the pointer’s useability, including:
  - A simplified case exposing only the essential button.
  - A pistol-grip design with trigger-actuated input.
  - A laparoscopic-style grip activating the pointer’s button when handles are squeezed.
- 3D printed prototypes and assembled them with a rod to simulate surgical use.
- Evaluated usability through simulated scenarios and feedback from the research team.
- Attended a conference on A.I. in surgery to gain insights into the field and inform device design.





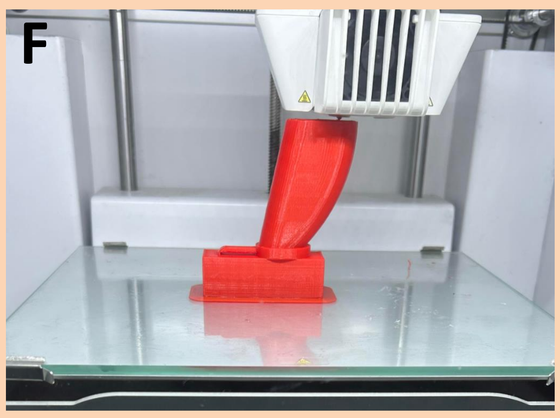


Image Descriptions

C. Fusion 360 design of pistol-grip interaction method
D. Fusion 360 design of laparoscopic grip interaction method
E. Ergonomic prototype of pistol-grip design
F. Prototype being 3D printed

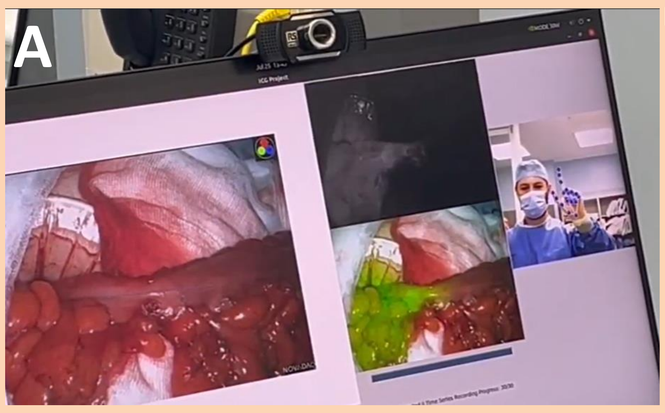


Image Descriptions

A. Hand gesture interaction method
B. Indocyanine Green Fluorescence Angiography (ICGFA) interpretation by the A.I. computer system

Conclusion

- Based on feedback from surgeons, the pistol-grip design with the trigger mechanism emerged as the preferred method. Surgeons found this design to likely be the most comfortable and intuitive.
- The simplified pointer with a single exposed button was also well-received, offering a straightforward and efficient solution.
- By ensuring that these devices are encased in a sterile drape, they can be integrated into surgical environments without compromising cleanliness or safety.
- The findings support the viability of wireless pointer devices as effective tools for enhancing surgeon-AI interaction during surgery.
- Further development and testing will be necessary to refine the designs and fully integrate them into surgeries.

References

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