Deep Learning for Robot-Assisted, Minimally Invasive Esophagectomy

Background

Robot-assisted minimally invasive esophagectomy for cancer of the esophagus is one of the most complex surgical procedures, during which the surgeon relies completely on live endoscopic imaging. Several vital anatomical structures are located withing the operating field, such as the heart, pleura and lungs, trachea and bronchus, aorta, vena cava, and recurrent laryngeal and vagus nerves (Fig.1). However, injury is easily inflicted to these structures due to their connectedness to the esophagus and the narrow operating space. Knowing the precise location of these vital anatomical structures during surgery would help the surgeon to avoid unnecessary damage and improve the clinical outcome, especially when the surgeon has little experience yet with this type of surgery.

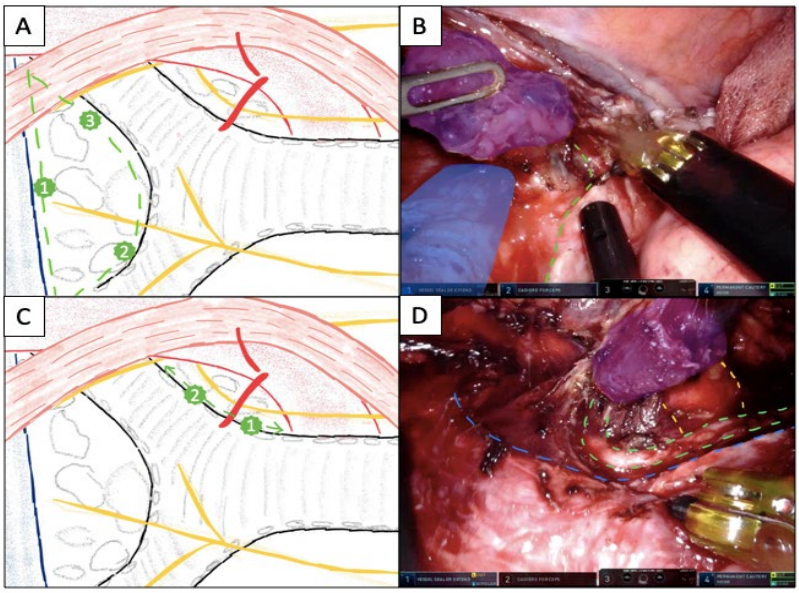

Fig.1: Examples of intraoperative images (right) and corresponding diagrams of the surgical site (left). The lymph nodes are highlighted in purple, the right bronchus is shown in green. The blue dotted line marks the left edge of the trachea. The yellow dotted line in panel D represents the arch of the aorta.

Deep learning, and particularly convolutional neural networks (CNNs), are currently gaining momentum in many image-based fields, and the technology has already dramatically advanced our ability to automatically analyze medical images. CNNs have been used to some extent to analyze endoscopic images, such as anatomical classification or automatic tool detection, but very few studies have focused on the recognition of anatomical structures in endoscopic images. A major challenge in endoscopic video processing is the time dimension: most existing methods consider each image frame independently, but consecutive frames might contain essential information on which anatomical structures are in and out of the endoscopic view. Continuous deformations in the soft tissues caused by breathing, heartbeat, and clamping by surgical tools complicate matters even further.

Objective & study design

The aim of this project is to develop a novel deep learning-based method to automatically recognize vital anatomical structures in endoscopic esophagectomy images. The project will comprise of the following steps:

a) Data acquisition and pre-processing: acquire anatomical annotations of the anatomical site for a selection of the available video data. In this phase of the project, the student will gain understanding of state-of-the-art robot-assisted surgical workflows and techniques, and consult with gastrointestinal oncologic surgeons of the UMC Utrecht on which structures are

most relevant to detect during surgery. Initially, we will probably focus on one or two anatomical structures, such as the trachea or the aortic arch.

b) Develop a custom CNN architecture that takes video images as input (2D images + time component) and gives anatomical annotations as output.
c) Train the network on data provided by UMC Utrecht: ~ 500 videos of robot-assisted surgeries are available from the past 15 years. The algorithm will be validated by evaluating its the performance on a hold-out test set and asking feedback from the involved clinicians.

Industrial collaborations
The Department of Surgical Oncology of the UMC Utrecht has an ongoing research collaboration with Intuitive Inc., the maker of the da Vinci surgical system based in Silicon Valley (US), in the area of telementoring and augmented reality.

Student background
(Bio)Medical Engineering, Medical Technology & Physics, Applied Mathematics, Computer Science (Machine Learning), or similar.

Duration
6-12 months

Student skills
Deep learning, Python programming, modeling, endoscopic video analysis

Location
UMC Utrecht & TU Eindhoven

Involved supervisors
- Prof. dr. J.P. (Jelle) Ruurda (hoogleraar chirurgie), Department of Surgical Oncology, UMC Utrecht
- Cas de Jongh, MD (PhD student), Department of Surgical Oncology, UMC Utrecht
- Dr. M.A.J.M. (Maureen) van Eijnatten (Assistant Professor), Medical Image Analysis group, Biomedical Engineering, TU Eindhoven

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