Towards Augmented Reality for Lung Surgery

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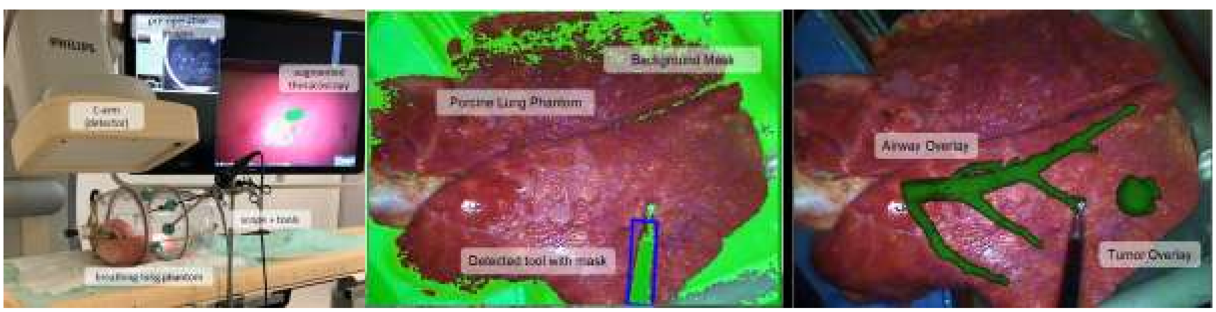
Purpose: A minimally invasive surgical technique, video assisted thoracoscopic surgery or VATS, has emerged over the last 15–20 years as the *de facto* standard of care for lung tumor resection, comprising ~60% of surgical cases in the US [1]. Surgeons insert tools through small ports between the ribs, one tool being a thoracoscope used to view the inside of the chest.

The surgical challenge in VATS is to localize lung tumors in the thoracoscope view, in order to resect the tumors with safe margins while sparing healthy tissue. Here we propose the use of augmented reality (AR) for image guidance, *with a focus on the particular challenges of lung surgery* and our corresponding solutions. Applied to lung surgery, existing AR approaches [2] face key limitations in tissue tracking: (1) irregular motion from surgical manipulation (stretching, grasping), (2) physiological motion, (3) tool occlusion (4) high degree of lung tissue deformation, and (5) discerning lung tissue from the surrounding anatomy (e.g., pericardial sac, ribcage).

Methods: Our augmented VATS solution (Fig. 1a) overlays graphical objects, such as a tumor (Fig. 1c), on the thoracoscopic video. After an initial overlay registration, background subtraction [3] and multiple HSV masks are used to identify and remove the background and tools (Fig. 1b). These masked frames supply a dense optical flow algorithm [4] with flow smoothing. Tracked motion is then fit to an affine model using least-squares minimization, and the overlay graphic is transformed accordingly. Overlays are updated for each new video frame to follow the motion of its underlying tissue base.



(a) (b) (c)

Fig. 1: (a) Augmented VATS setup, (b) tool and background mask, and (c) tumor overlay on porcine lung. An airway overlay is also shown to demonstrate extended capabilities.

Results: The pipeline was tested with video of size 720×486 px at 24 fps. A computational rate of 10 Hz was achieved using a C++ implementation on a GPU. In our *in vitro* setup (Fig. 1a), the overlay was qualitatively assessed to adhere to anatomical features of a porcine lung specimen under simulated surgical motions such as gross manipulation, grasping, and stretching.

Conclusions: Our experimental setup and methods demonstrate potential in recreating and addressing the particular challenges of AR for lung surgery. Future work includes quantifying the performance, integrating preoperative imaging, and developing clinically viable workflows.

References: [1] Healthcare Cost and Utilization Project (HCUP), https://www.hcup-us.ahrq.gov. [2] H. Elhawary, *Int. J. Med. Robot. 2011*. [3] A. Godbehere, *Am. Control Conf. 2012*. [4] Brox, *Eur. Conf. Comput. Vis. 2004*.

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