Evaluation of Surface Feature Persistence during Lung Surgery

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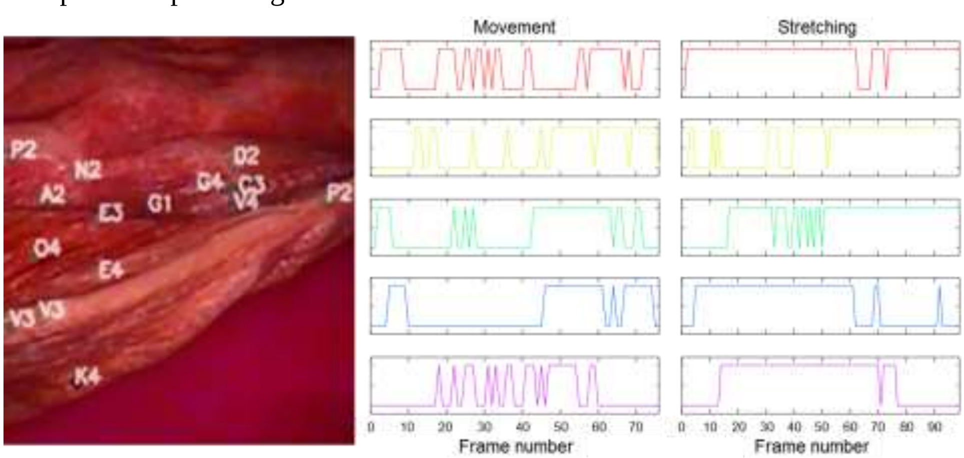
Introduction: Minimally invasive surgery is the preferred treatment option for patients with early stage lung cancer. As lung cancer screening programs are adopted, localizing small, non-palpable nodules during surgery will become more challenging. CT/CBCT guided placement of markers has evolved to aid in nodule localization [1]. However, there are several disadvantages with marker insertion, so marker-less approaches are under investigation. Some alternatives include the fusion of pre-operative anatomical images (i.e. CT, MR) with intra-operative endoscope images [2] and visual servoing [3]. In either method, tracking algorithms can be used to track the endoscope position. In this paper, we evaluate the persistence of tracking lung surface features visible in endoscopy during lung surgery.

Materials and Methods: Surface feature tracking based on computer vision algorithms including SURF and optical flow [4] were used with endoscopy video-feeds acquired from an *ex vivo* porcine lung. Whereas Elhawary et al [4] used surface feature tracking to account for predictable motion of stiff cardiac tissue, in the present study we are tracking gross manipulation of loosely-structured tissue in lung surgery. The lung was manipulated to simulate surgical activity using laparoscopic instruments. Endoscopic videos (720x486 resolution, 30 fps) were acquired of (1) basic movement, and (2) stretching; durations were 10.7 and 11.6 seconds respectively.

Results and Discussion: We evaluate the persistence of tracking lung tissue, subject to these surgical conditions, by tracking the rate at which distinct features (identified by the SURF algorithm) appear throughout manipulation. The ground truth is that features always remain within the field of view of the endoscope. Figure 1 tabulates the appearance rate for the five most persistent SURF features in each test case. Features were tracked more frequently, lost fewer times, and recovered more quickly in the stretching condition compared to movement. For the movement case, at least one top-5 feature persisted 83% of the time; when a top-5 feature was absent, it was recovered within 2.7±0.8 frames. In the stretching case, there were at least two top-5 features 99% of the time, the top feature persisting across 92 of 99 measured frames.



	Feature	% of frames with feature tracked	# of times feature is lost	Average # of frames before lost feature is found
Movement	1	48.7	10	4.7
	2	43.4	8	5.4
	3	42.1	7	7.3
	4	39.5	4	14.3
	5	30.3	10	3.1
Stretching	1	92.9	2	4.0
	2	67.7	5	7.0
	3	76.8	6	2.2
	4	60.6	3	15.0
	5	62.6	2	2.0

Figure 1. (*Left*) Features tracked in endoscope view. (*Middle*) Top-5 features tracked per frame. High level indicates feature is visible in the frame, while low level indicates absent feature. (*Right*) Tabulated data from top-5 features.

Conclusions: The results indicate that lung tissue can be tracked through a variety of gross manipulations, which demonstrates the potential for a marker-less tracking method for nodule localization. Future studies should include other types of manipulations encountered during surgery such as dissection and leaving/entering the endoscopic view; other performance improvements include computational frame rate and adaptation to intra-operative imaging and surgical conditions.

References: [1] Gill R, *J Surg Oncol* 2015, 112:18–25 [2] Bernhardt S, *Med Im Anal* 2017, 37:66–90 [3] Popovic A, *Proc 2010 3rd IEEE RAS & EMBS*, 106–113 [4] Elhawary H, *Int J Med Robotics Comput Assist Surg* 2011, 7:459–468