

Image-based Incision Detection and Topological Intraoperative 3D Model Update in Augmented Reality Assisted Laparoscopic Surgery

Tom François^{1,2}, Lilian Calvet^{1,3}, Callyane Sève-d'Erceville¹, Nicolas Bourdel¹, Adrien Bartoli¹

¹ *Université Clermont-Auvergne, Institut Pascal, Clermont-Ferrand, France*

² *Be-Ys Research, Châtelaine, Switzerland*

³ *INP Toulouse, Toulouse, France*

Introduction

Augmented Reality allows one to visualise the internal structures of an organ in laparosurgery. It requires one to register a preoperative 3D model obtained from MRI or CT to laparoscopic images. Registration is a challenging problem because of the deformations. Existing methods assume a fixed topology of the model, which leads to registration failure during organ incision. Registering and handling topological model changes forms an open problem. Solving it would extend gesture guidance to some critical parts of surgical procedures.

Methods

We propose *ImTopUp*, an image-based topological update registration framework for incision aware registration in augmented laparosurgery, described in figure 1. [1], which we named *GeoTopUp*, detects incisions with a geometric criterion using keypoint tracks across the laparoscopic video. It does not use dense pixel information indicating organ incision from colour change or bleeding. In contrast, *ImTopUp* uses image-based incision detection with UNet [4] trained from 181 incision examples from 10 uterus surgeries. Once detected, the incision is transferred to the model. The transfer uses a warp to a reference image pre-registered to the model. The model topology is then updated and registration to the input image solved.

Results/Discussion

The proposed incision detector has a mean precision, recall and f1 score of 0.05, 0.36, and 0.08 respectively from 10-fold cross-validation. Our training dataset is still small with respect to the complexity of the task and the high variability of the input images. We expect a significant performance boost by expanding our dataset.

The registration pipeline has been evaluated on ex-vivo kidneys. The registration performed with the initial 3D model, denoted *baseline*, has been compared to our implementation *GeoTopUp* and *ImTopUp*, with controlled incision detection, as shown in figure 2. Overall, updating the model topology with *ImTopUp* improves the registration accuracy by 5% on average compared to *baseline*. *GeoTopUp* failed in approximately half of the experiments. When it worked, it was outperformed by *ImTopUp*. *GeoTopUp* either detects many false cut points that eventually make the registration fail or detects no incision. The incision localisation in *GeoTopUp* was generally poor.

Conclusions

ImTopUp is the first framework which detects organ incisions in laparoscopic images and uses this

information to update the topology of a preoperative 3D model. Our preliminary experiments show that this improves registration accuracy. The location of the bottom of the incision remains imprecise, as shown in figure 2. We now plan to expand our training dataset and to combine *ImTopUp* and *GeoTopUp* to improve precision and robustness.

Disclosure

Authors have **no financial interest** or **relationship** to disclose regarding the subject matter of this presentation.

Affix

References

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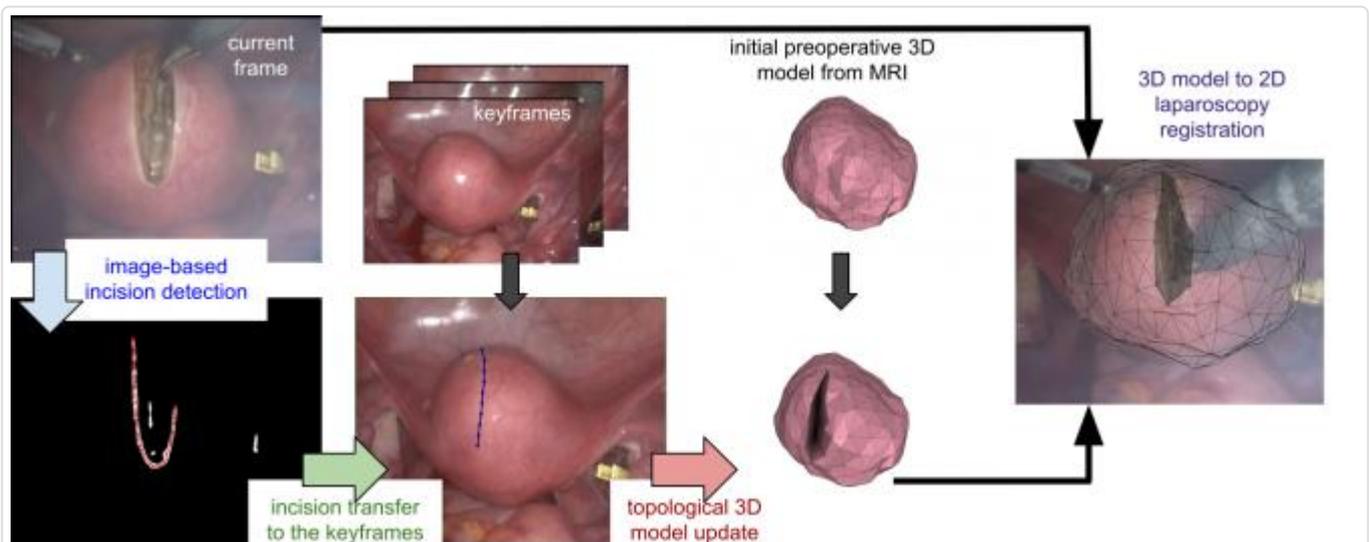


Figure 1: Description of the complete proposed registration pipeline ImTopUp.

Left: Image-based incision detection. Middle: Incision-transfer to the keyframes and topological 3D model update. Right: Registered 3D model projected onto the current frame.

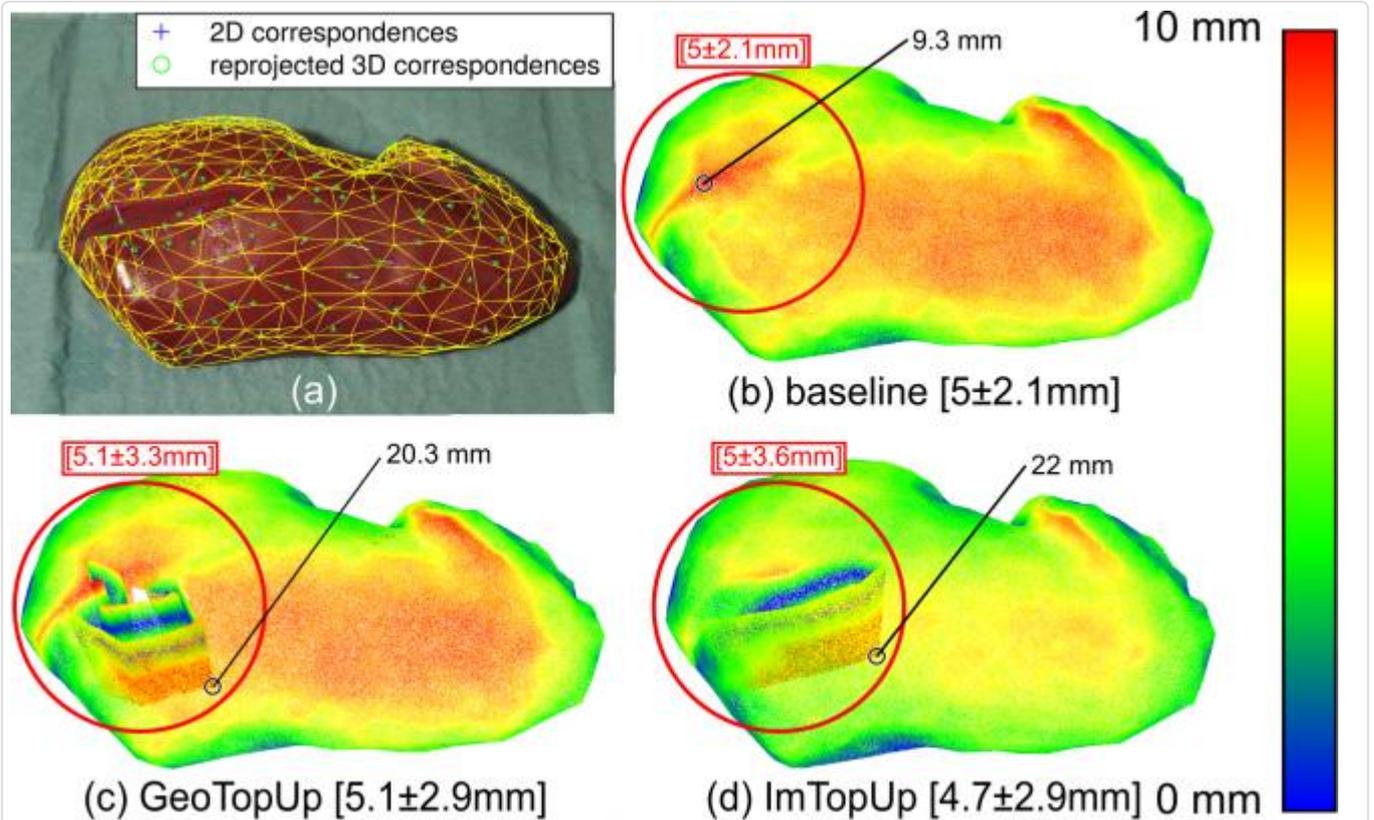


Figure 2: Visual results for registration evaluation on an ex-vivo porcine kidney.

(a) Reprojection error between correspondences (white line) for the ImTopUp registered 3D model (yellow outline). The mean reprojection error is 8.85px for a 1280x720 image resolution. (b-d): Distances from the registered model to groundtruth with methods (b) baseline, (c) GeoTopUp and (d) ImTopUp (proposed). Results for distances are expressed with [mean±standard deviation] for the external surface and for a cropped region around the incision (red circle) in red. Maxima distance locations are outlined in the black circles. The dimensions of the kidney are 140x80x25 mm.