Liver Surface Reconstruction for Image Guided Surgery

Congcong Wang[1], Faouzi Alaya Cheikh[1], Mounir Kaaniche[2], Ole Jacob Elle[3, 4]
[1]Norwegian Colour and Visual Computing Lab, Norwegian University of Science and Technology, Norway.
[2]L2TI-Institut Galilee, Universite Paris 13, Sorbonne Paris Cite, Villetaneuse, France.
[3]The Intervention Centre, Oslo University Hospital, Oslo, Norway.
[4]The Department of Informatics, University of Oslo, Oslo, Norway.

INTRODUCTION

Aim:
- Reconstruct 3D liver surface based on stereo vision technique.
- Serve as intra-operative information for pre-operative to intra-operative registration.

Image-based navigation systems ultimately based on image pre-processing, segmentation, 3D modeling, registration and visualization techniques, increase the ability of the surgeon to plan and perform surgery safely and accurately.

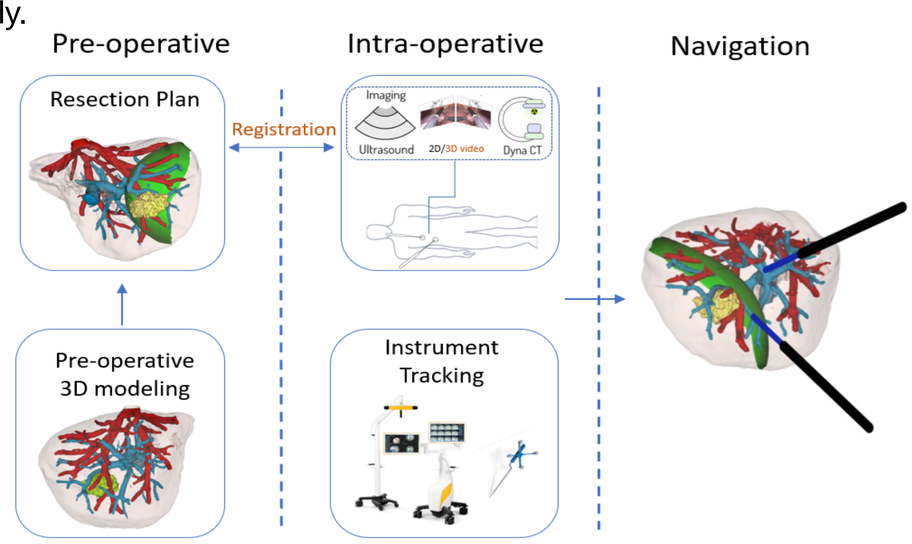
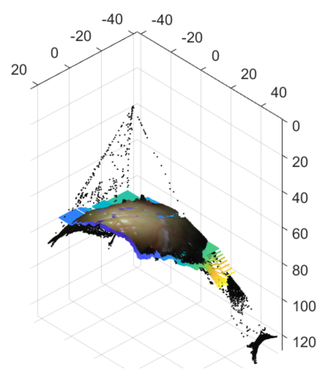


Fig. 1 Overview of an image guided surgery system

Stereo laparoscopes have been introduced to provide a 3D view of the organ for the surgeons intra-operatively, as well as to compute depth information of the organ.



METHOD

1. Variational Disparity Estimation

The gray values and gradient of the two corresponding pixels in the left and right images are the same.

- Gray value

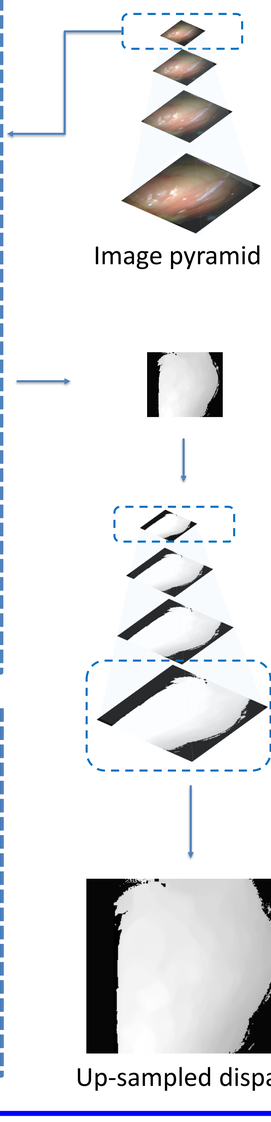
$$|\mathrm{I_l}(\mathrm{i},\mathrm{j}) - \mathrm{I_r}(\mathrm{i}-\mathrm{d_{i,j}},\mathrm{j})|$$

- Gradient

$$|\nabla \mathrm{I_l}(\mathrm{i},\mathrm{j}) - \nabla \mathrm{I_r}(\mathrm{i}-\mathrm{d_{i,j}},\mathrm{j})|$$

The organ surface is smooth, so we assume that the disparity is smoothly distributed.

- Pixel wise $|\nabla d|$
- Non-local $\sum_{(i,j)\in\Omega_d}\sum_{(i',j')\in N_{i,j}}|d_{i,j}-d_{i'j'}|$



2. Disparity Up-sampling

A modified bilateral filter [1] is used for up-sampling.

$$\tilde{d}_p = \frac{1}{k'_p}\sum_{q_\downarrow\in N} I_{q_\downarrow} f(\| p_\downarrow - q_\downarrow \|)\cdot$$

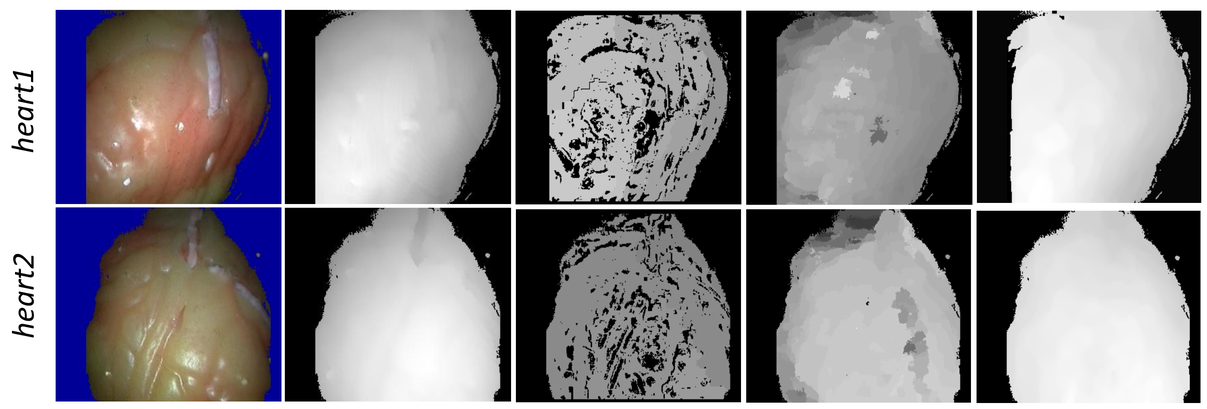
$$\left[\alpha(\Delta N)g\left(\| \tilde{\mathbf{I}}_p - \tilde{\mathbf{I}}_q \|\right) + \left(1-\alpha(\Delta N)\right)h(\| d_{p_\downarrow} - d_{q_\downarrow} \|)\right]$$

RESULTS

Dataset [2]
- Cardiac phantom datasets with ground truth: *heart1* and *heart2*.
- Porcine liver datasets without ground truth: *liver1*, *liver2* and *liver3*.

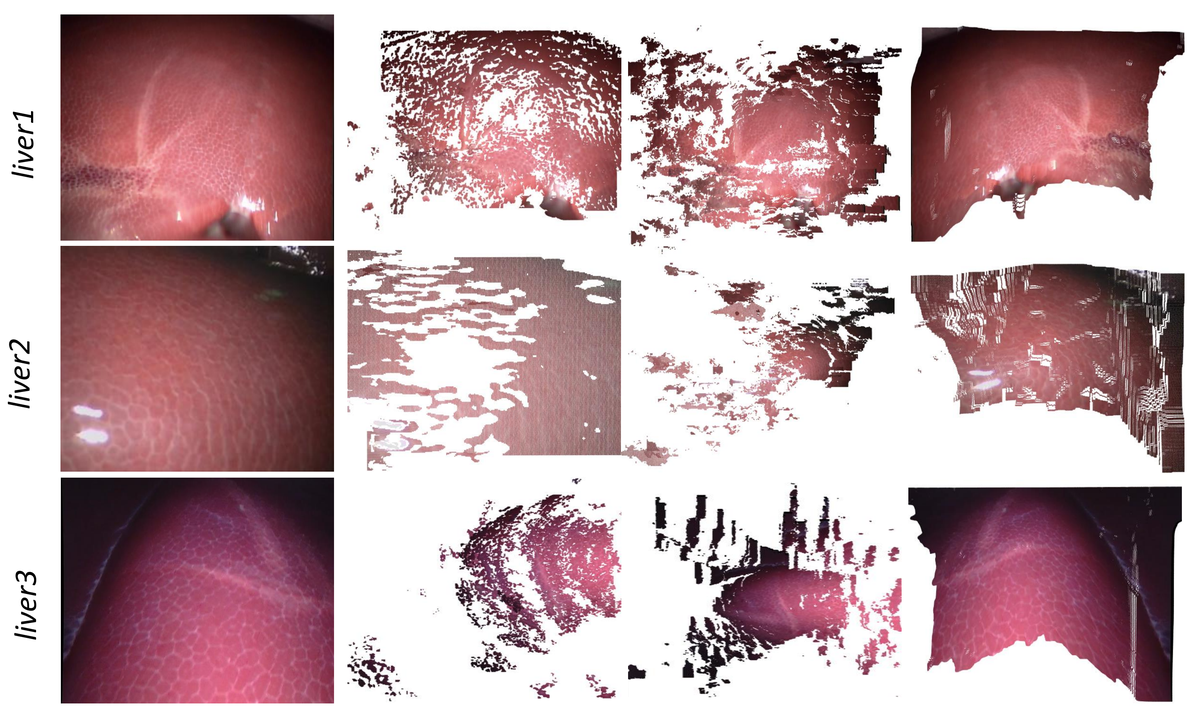
Table. 1 MAE (mm) and % Match for phantom datasets *heart1* and *heart2*.

	heart1		*heart2*	
Methods	MAE(mm)	% Match	MAE(mm)	% Match
Proposed	**2.16 ± 0.65**	**97.25 ± 1.13**	**2.14 ± 0.83**	**99.96 ± 0.11**
QuasiDense[3]	2.33 ± 0.61	78.64 ± 2.00	2.26 ± 0.52	80.64 ± 1.87
FCVF[4]	4.43 ± 0.81	95.96 ± 1.57	4.21 ± 1.20	88.92 ± 2.38



(a) Original image (b) Ground truth (c) QuasiDense [3] (d) FCVF[4] (e) Proposed

Fig. 2 Disparity results of *heart1* and *heat2*.



(a) Original image (b) QuasiDense[3] (c) FCVF[4] (d) Proposed

Fig. 3 Estimated surface for liver datasets.

CONCLUSION

- Dense surface reconstruction method is proposed.
- Proposed method outperforms QuasiDense [3] and FCVF [4] in terms of accuracy and % Match.

FUTURE WORK

- Pre-processing of the stereo images: edge enhancement, etc.
- Taking into account edge information and occlusion in the energy function.

REFERENCES

[1] Chan, D., Buisman, H., Theobalt, C., and Thrun, S., \A noise-aware filter for real-time depth upsampling," in [M2SFA2], (2008).

[2] Hamlyn Centre Laparoscopic / Endoscopic Video Dataset, http://hamlyn.doc.ic.ac.uk/vision/. Accessed: 2017- 10.

[3] Stoyanov, D., Scarzanella, M. V., Pratt, P., and Yang, G.-Z., "Real-time stereo reconstruction in robotically assisted minimally invasive surgery," in [MICCAI], 275-282, Springer (2010).

[4] Hosni, A., Rhemann, C., Bleyer, M., Rother, C., and Gelautz, M., "Fast cost-volume filtering for visual correspondence and beyond," *IEEE TPAMI,* **35**(2), 504-511 (2013).

NTNU, P.O.Box 191, N-2802, Gjøvik, Norway

congcong.wang@ntnu.no