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# Validation of stereo vision based liver surface reconstruction for image guided surgery

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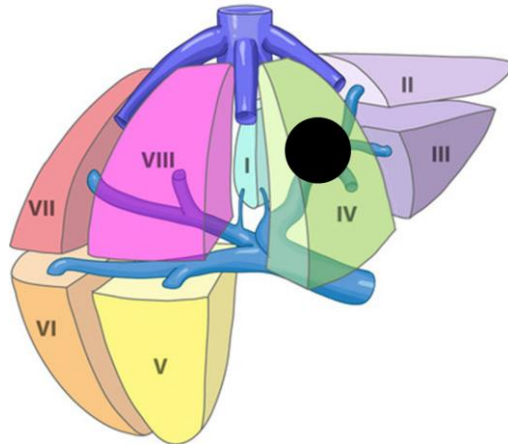
\*Denotes equal contributions and listed in alphabetical order.

# Introduction

- Laparoscopic Liver Resection



- Liver Metastasis from Primary Colorectal Cancer (CRM) affects 550,000 patients p/y.
- Post-operative reoccurrence of 80% of patients for Colorectal Liver Metastases.
- Parenchyma Sparing approaches to spare healthy liver tissue.
- Laparoscopic Liver Resection presents great benefits for patient recovery.



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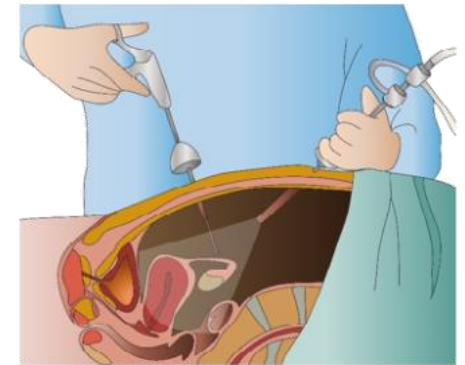
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# Introduction

- Laparoscopic Liver Resection (2)



- Surgeon can only visualize the anatomy of the patient through the laparoscope camera. The field of view is greatly reduced with respect to open liver surgery.
- Anatomical understanding only through preoperative CT/MRI scans.



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# Image Guided Surgery (IGS)

## Introduction

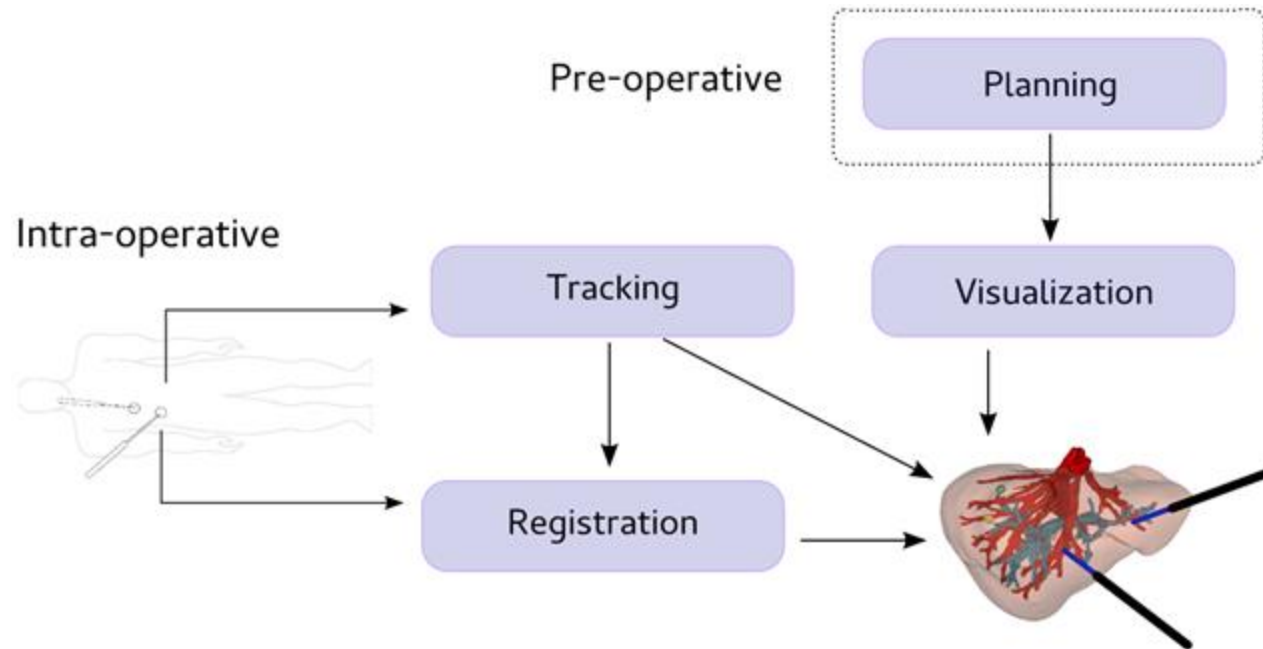
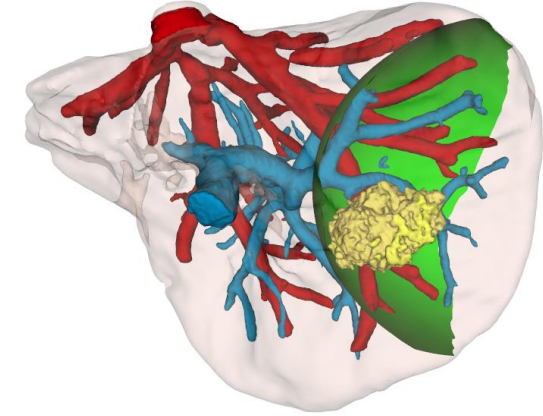
Stereo Reconstruction

Validation

Conclusions

Future work

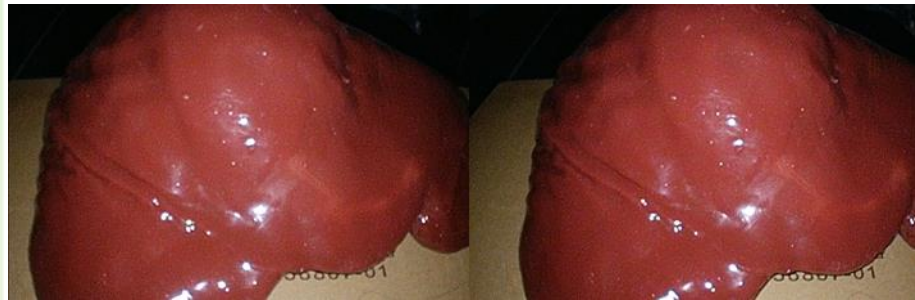
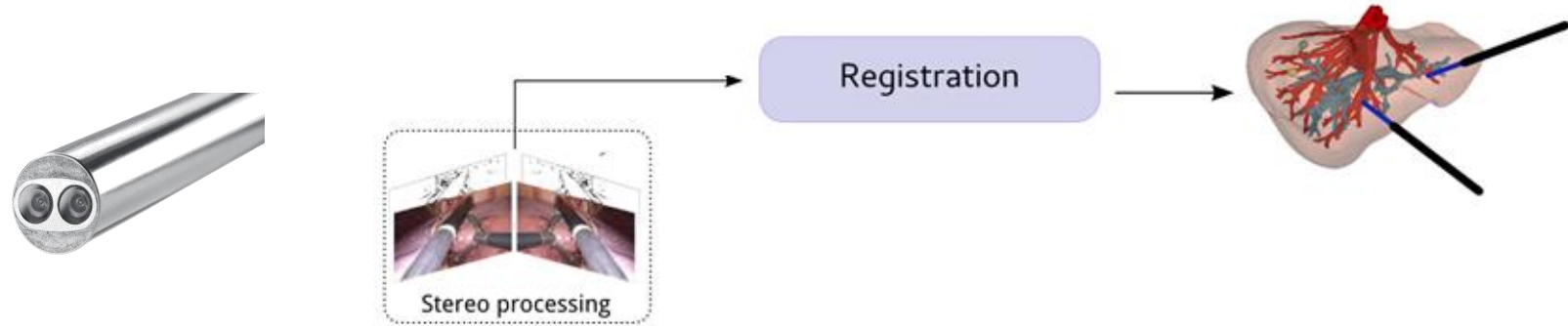
- Aid the surgeon by displaying preoperative resection planning with surgical navigation.



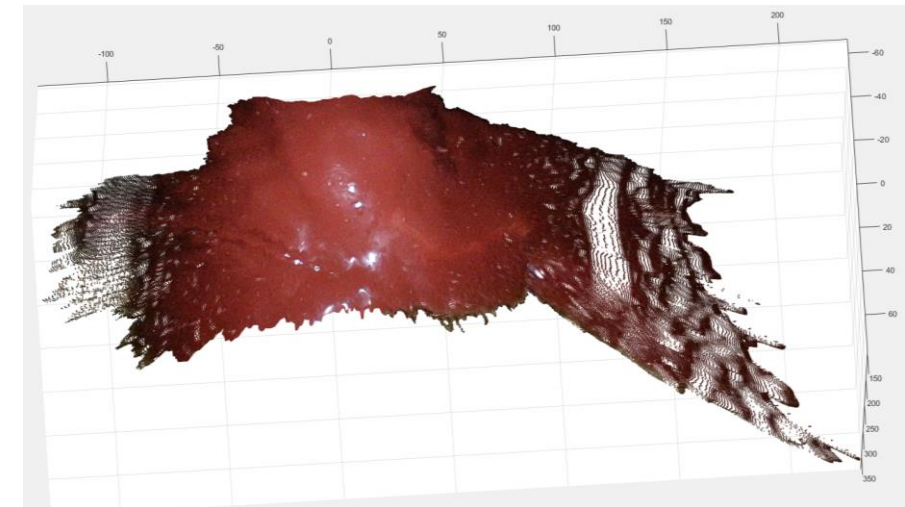


# Stereo video reconstruction

- We focus on navigation through Stereo Reconstruction.



2D left and right images



3D reconstruction

# Stereo-reconstruction Method

Introduction

Stereo Reconstruction

Validation

Conclusions

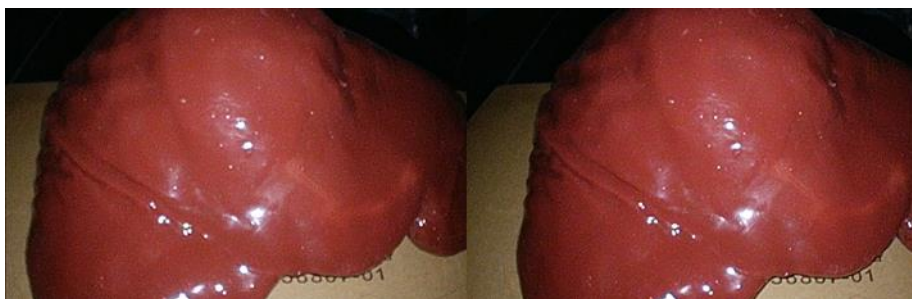
Future work

- Variational Method based on global image disparity<sup>1</sup>

Cost Function

$$E_{data}(d) = \underbrace{[I_l(i,j) - I_r(i - d_{i,j},j)]^2}_{\text{Pixel Intensity}} + \underbrace{\gamma[\nabla I_l(i,j) - \nabla_r^T(i - d_{i,j},j)]^2}_{\text{Gradient of the image}}$$

$E(d) = E_{data} + \underbrace{\lambda_s E_s + \lambda_{nl} E_{nl}}_{\text{Smoothing terms (local and non-local)}}$



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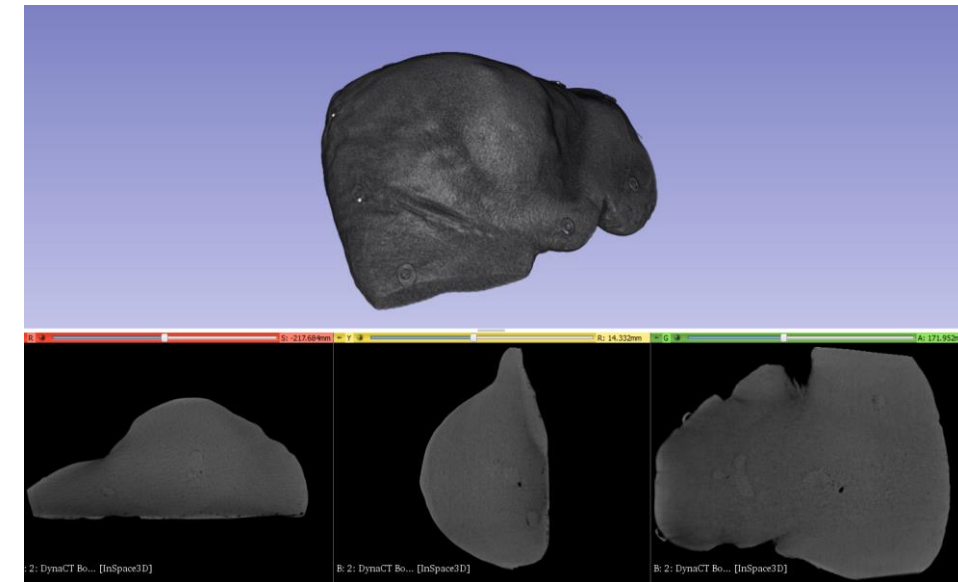
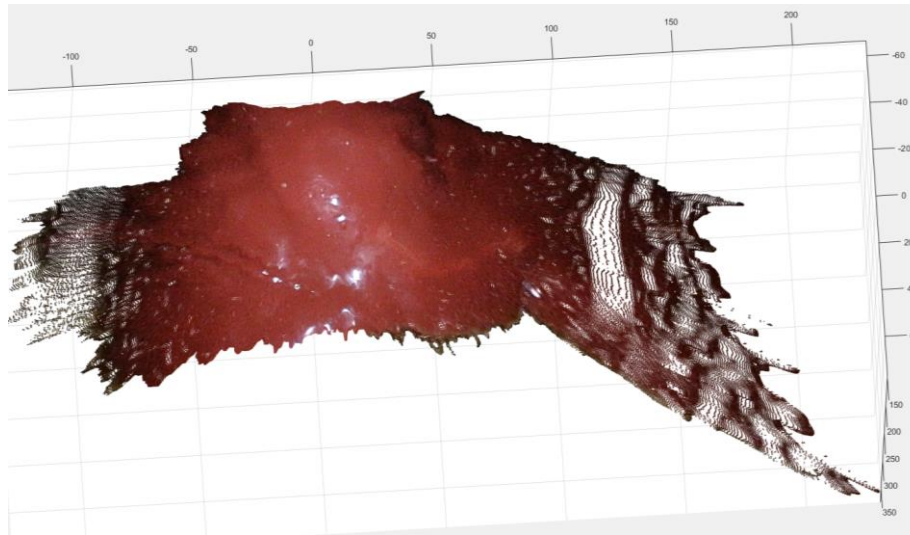


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[1] C. Wang et al., "Liver surface reconstruction for image guided surgery," SPIE Proceedings, March 2018 .

# Validation through Registration

- For IGS, we want to combine Intra-operative laparoscopic data to pre-operative CT/MRI volumes.



3D stereo-reconstruction



3D CT reconstruction

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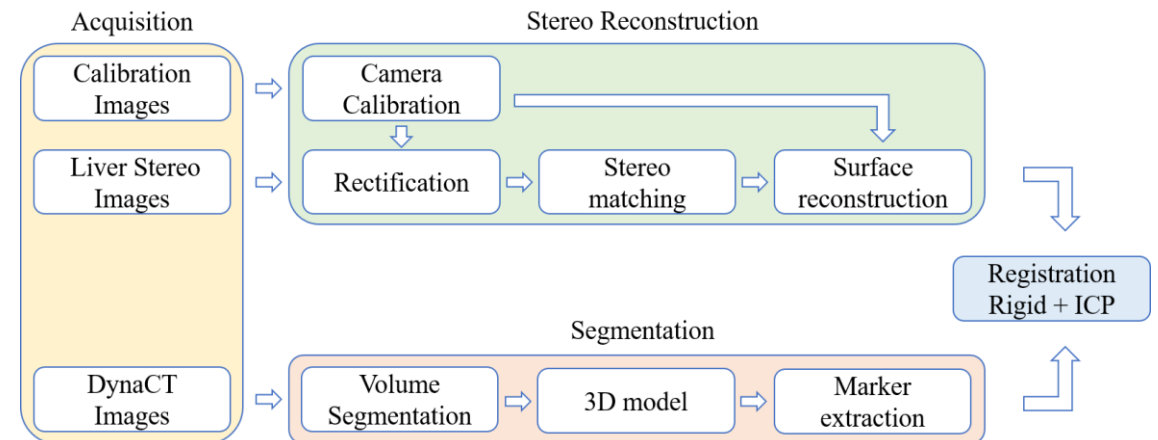
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# Validate the Reconstruction

- Workflow to check reconstructed liver surface.



- Patient specific liver phantom.
- Markers to register CT and Stereo.
- Refine through Iterative Closest Points (ICP) registration.





# Registered Surface to CT scan

Introduction

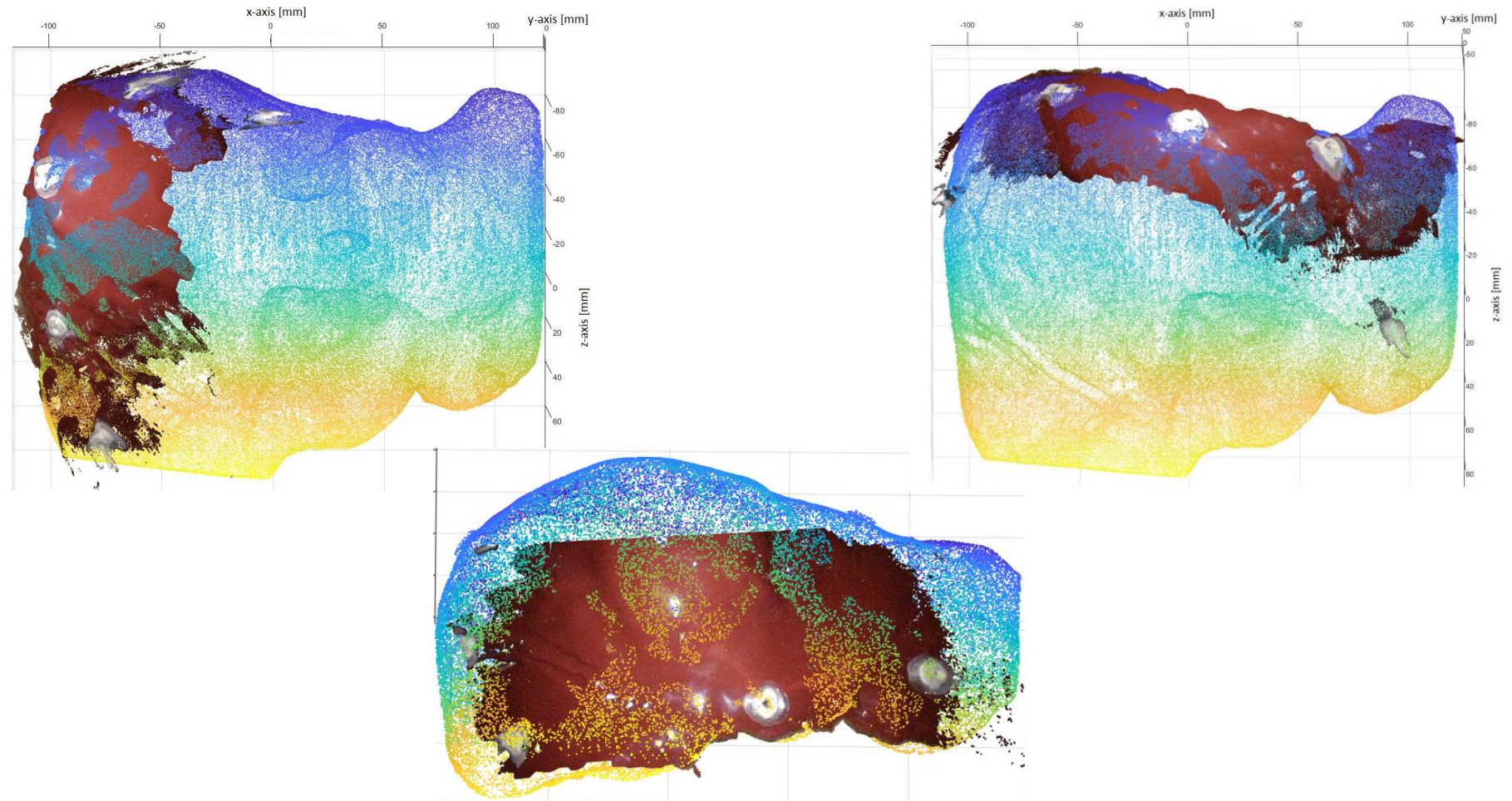
Stereo Reconstruction

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**Results**

Conclusions

- Examples of stereo-point clouds (Red) registered to the CT scan liver point clouds (Colour).



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# Measures of Accuracy

- Two measures of accuracy were used to evaluate:

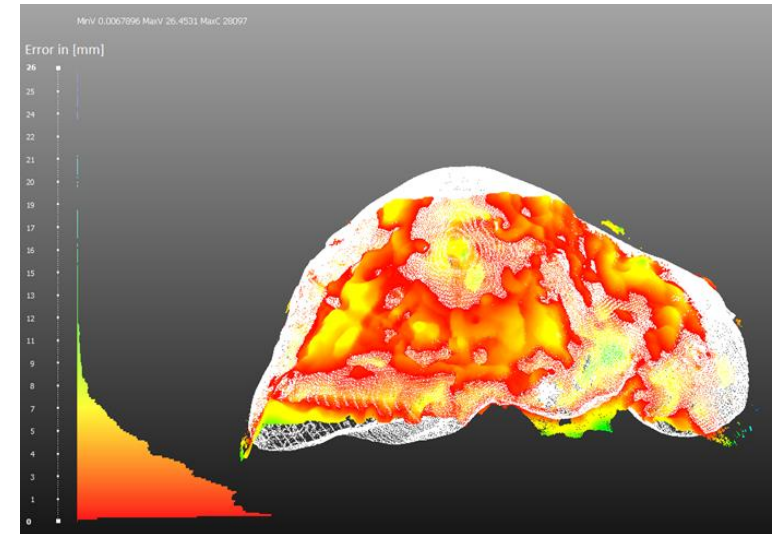
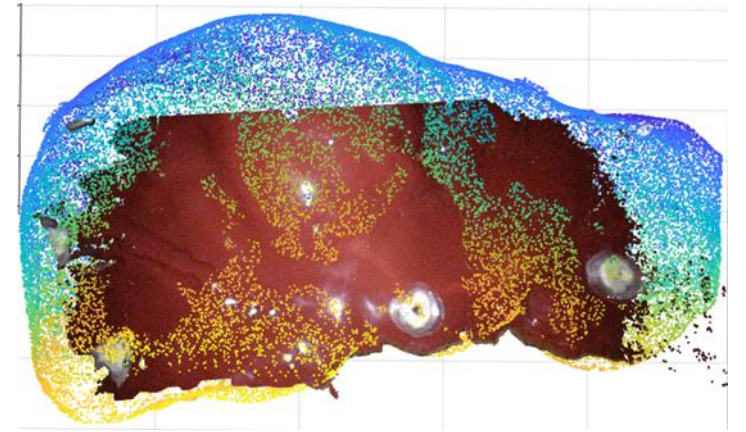
## Mean Absolute Error (MAE)

$$MAE = \sum_{(x,y,z) \in \Omega} |\hat{Y}(x,y,z) - Y(x,y,z)|$$

## Hausdorff distance (H)

$$h(A, B) = \max_{a \in A} \min_{b \in B} ||a - b||$$

$$H(A, B) = \max(h(A, B), h(B, A))$$



# Results

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- MAE and Hausdorff were tested on 2 datasets, (*Dataset1* and *Dataset2*) of 15 surface reconstructions for a total of 30 reconstructions.

TABLE 1. MAE AND HAUSDORFF IN [MM] IN TERMS OF MEAN  $\mu$ , STANDARD DEVIATION  $\sigma$  AND MAXIMA FOR *Dataset1* AND *Dataset2*.

	<i>Dataset1</i>	<i>Dataset2</i>
MAE ( $\mu \pm \sigma$ )	$4.6 \pm 1.0$	$4.4 \pm 0.8$
$max_{MAE}$	128.8	105.2
Hausdorff ( $\mu \pm \sigma$ )	$3.7 \pm 0.8$	$3.6 \pm 0.8$
$max_H$	78.5	106.6

- Results show an accuracy of  $\sim 4$  mm, with large outliers due to triangulation error, which is inherent to laparoscopic stereo video reconstruction.



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# Conclusions and Future Work

Introduction

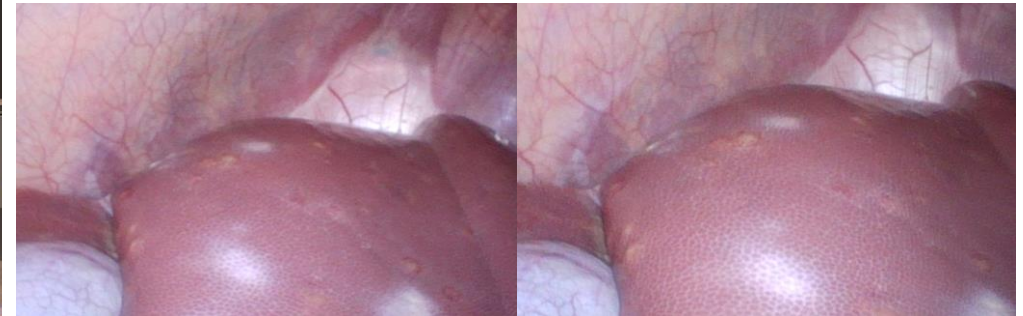
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- The reconstruction method can correctly reproduce (up to 4mm) the surface of the liver.
- Future studies will test the reconstruction method using data from both porcine (ongoing) and patient stereo laparoscopic video.



- Hand-eye camera calibration will be used instead of markers to perform registration to CT/MR scans.

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# Thank you!

Introduction

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**Conclusions**

Thank you all very much for the attention,  
Questions?

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