Instrument Segmentation in Hybrid 3-D Endoscopy using Multi-Sensor Super-Resolution

Sven Haase
29.11.2013
Pattern Recognition Lab (FAU)

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Outline

- Motivation
- Multi-frame Super-Resolution
- Tool Segmentation
- Experiments

Outline

- Motivation
- Multi-frame Super-Resolution
- Tool Segmentation
- Experiments

Motivation for Tool Segmentation

Intuitivesurgical.com

Motivation for Tool Segmentation

Assistance systems:

- Collision avoidance
- Camera positioning
- Automated procedures

Intuitivesurgical.com

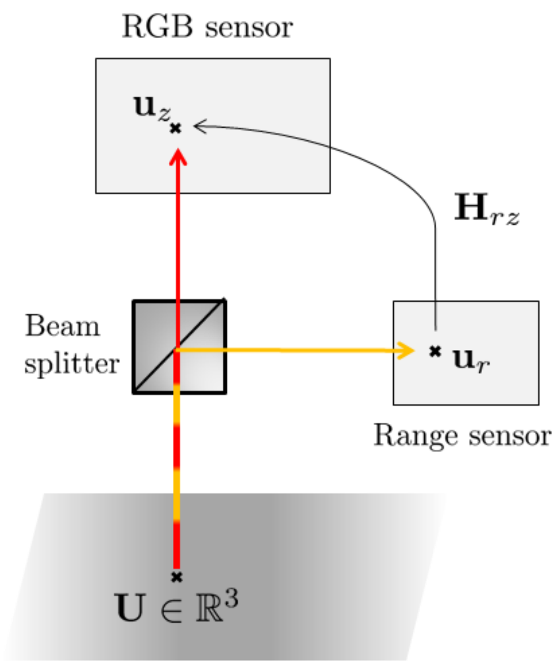
Hybrid 3-D Endoscopy

- Augment color with metric range information
- Rigid endoscope
- Time-of-Flight: 64×48 px
- Color: 640×480 px

Richard Wolf GmbH

Hybrid 3-D Endoscopy

- Augment color with metric range information
- Rigid endoscope
- Time-of-Flight: 64×48 px
- Color: 640×480 px

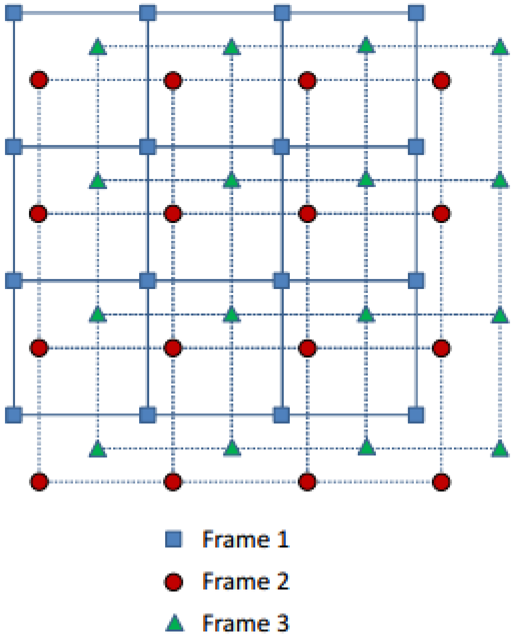


Outline

- Motivation
- Multi-frame Super-Resolution
- Tool Segmentation
- Experiments

Multi-frame Super-Resolution

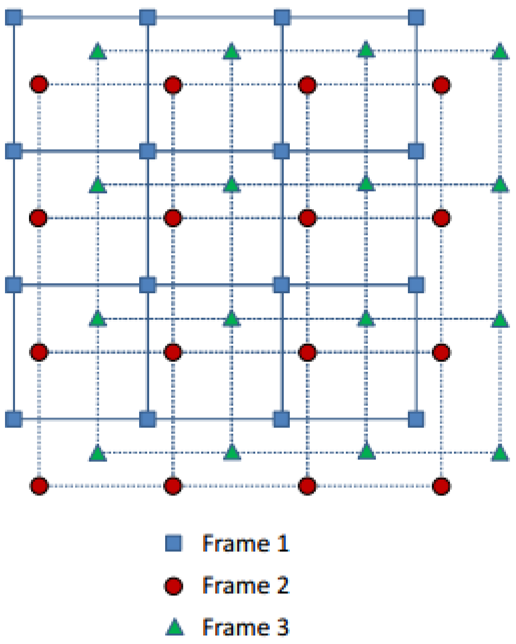
- Simultaneously increase image quality and spatial resolution
- Exploit small movements of the endoscope (e.g. jitter)



Multi-frame Super-Resolution

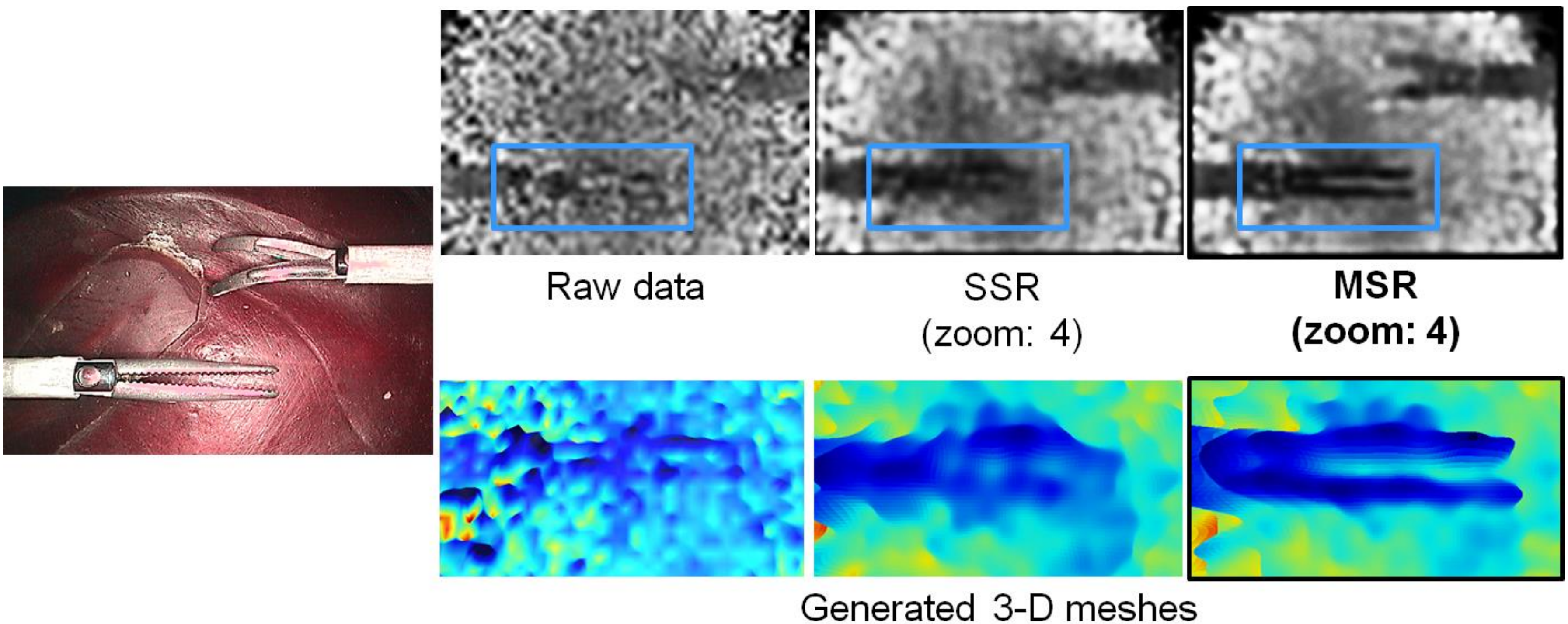
- Simultaneously increase image quality and spatial resolution
- Exploit small movements of the endoscope (e.g. jitter)

- ➢ Calculate the transformation on the color images
- ➢ Scale transformation into the range domain



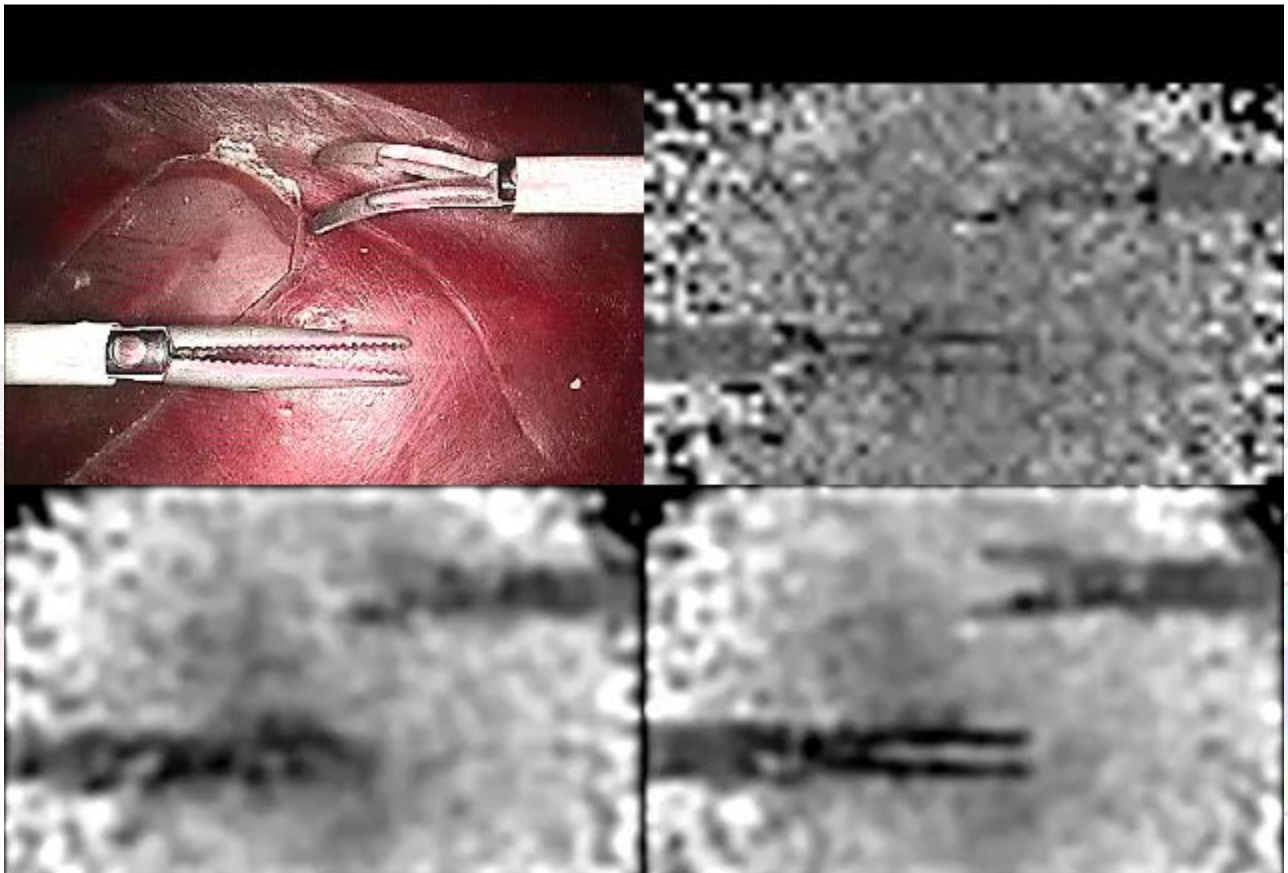
Multi-frame Super-Resolution [1]

[1] “ToF Meets RGB: Novel Multi-Sensor Super-Resolution for Hybrid 3-D Endoscopy”, MICCAI 2013

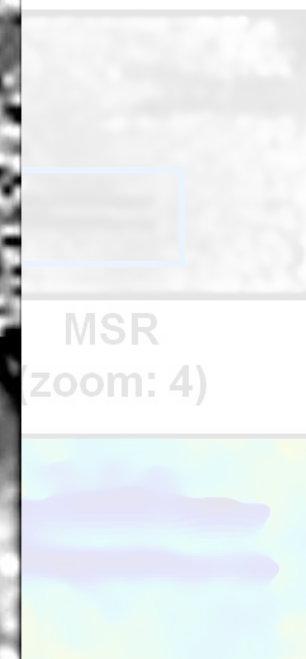


Multi-frame Super-Resolution [1]

[1] "ToF Meets RGB: Novel Multi-Sensor Super-Resolution for Hybrid 3-D Endoscopy", MICCAI 2013



Results obtained from a hybrid 3-D endoscope: RGB image (top left), raw range data (top right), single-sensor super-resolution (bottom left), our proposed multi-sensor approach (bottom right)



Outline

- Motivation
- Multi-frame Super-Resolution
- Tool Segmentation
- Experiments

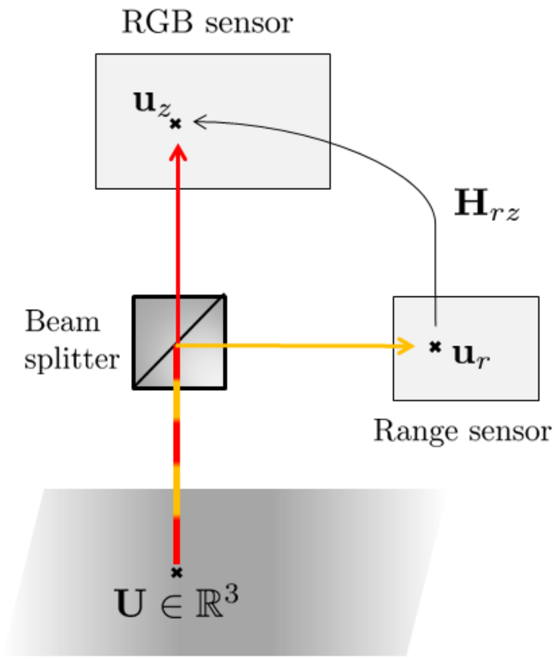
Tool Segmentation

Hybrid approach:

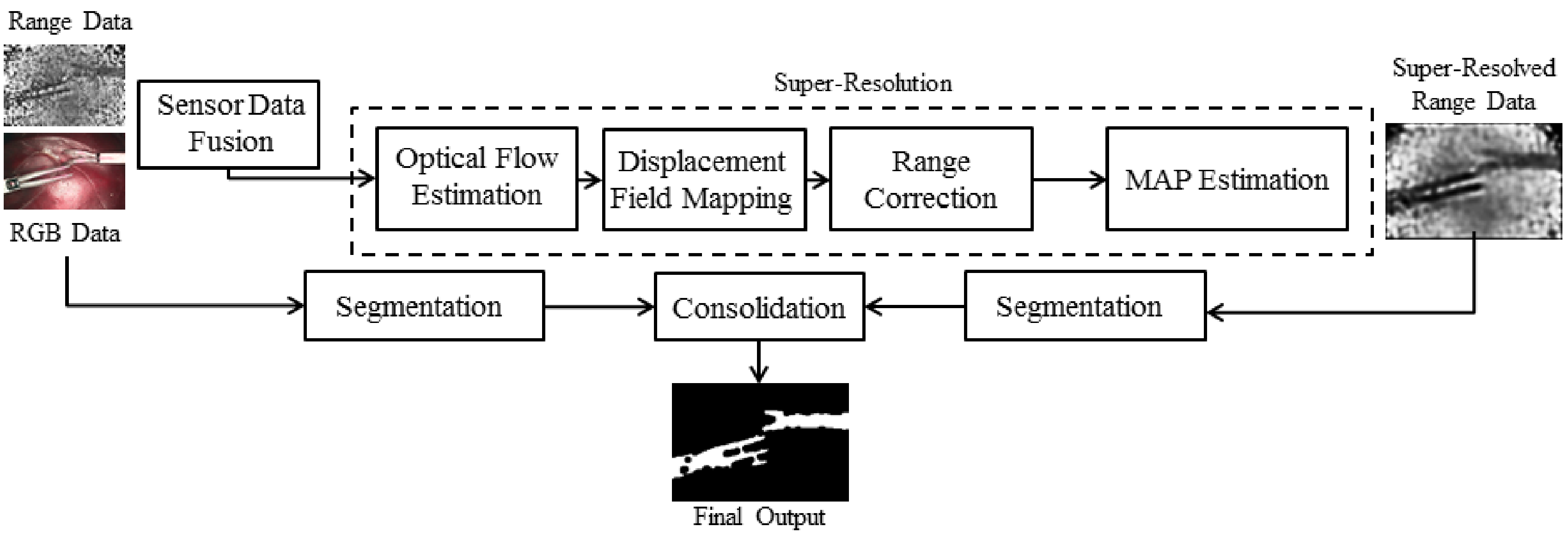
1. Segment tools in ToF data
   (tools are close to the sensor)

2. Segment tools in RGB data
   (tools are grayish → HSV)

3. Consolidate both results



Tool Segmentation



Outline

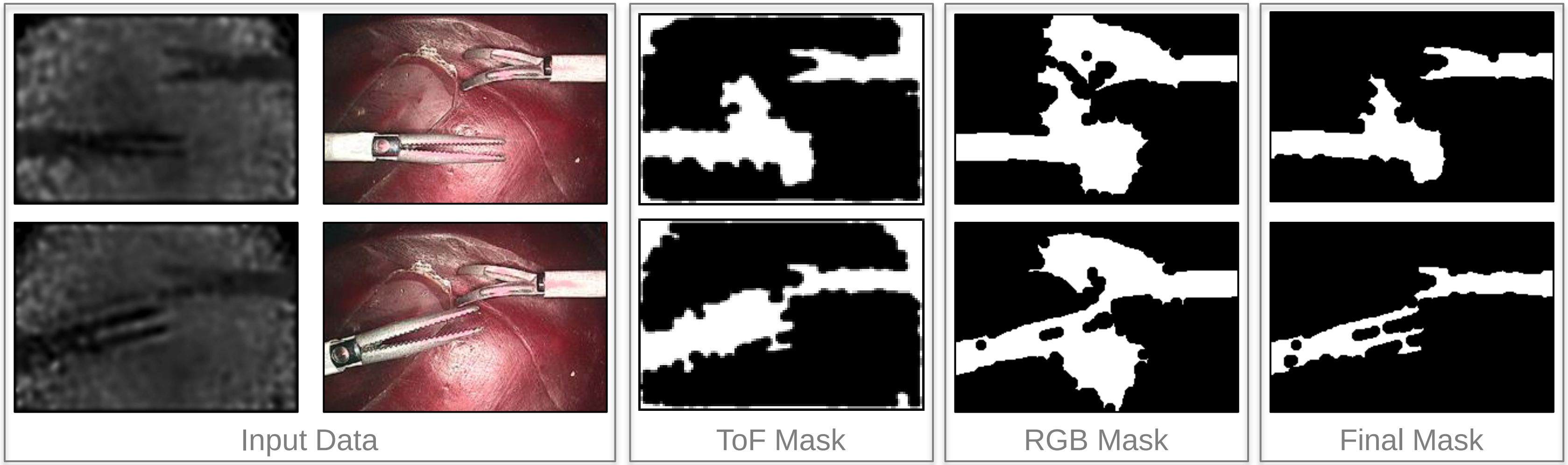
- Motivation
- Multi-frame Super-Resolution
- Tool Segmentation
- **Experiments**

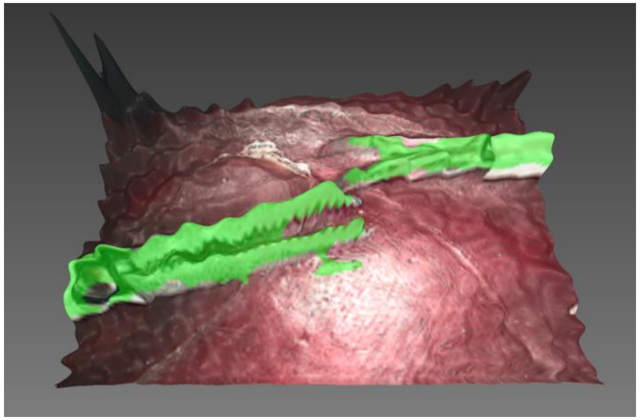
Experiments & Results

Ex-vivo experiments with two endoscopic tools in two scenarios with six frames each (→ 12 data sets) and expert labeled ground truth data.

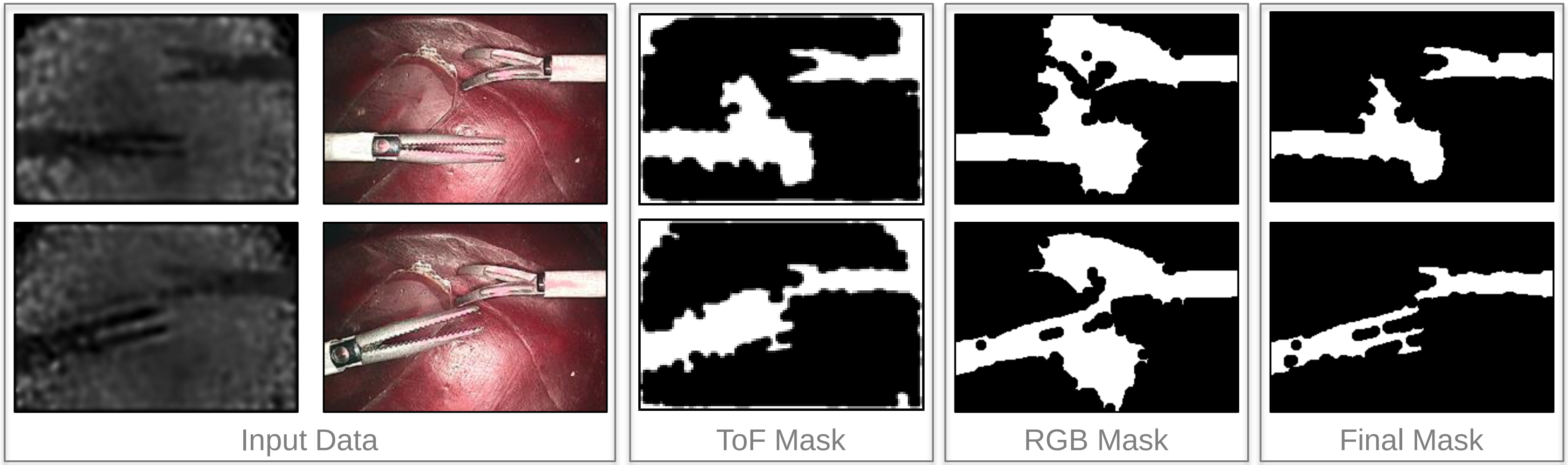
	ToF	Color	ToF & Color	Formula
Sensitivity	0.93	0.91	0.85	$\frac{TP}{TP + FN}$
Specificity	0.67	0.80	0.91	$\frac{TN}{TN + FP}$
F-Score	**0.50**	**0.61**	**0.73**	$\frac{2 \times TP}{2 \times TP + FP + FN}$

Experiments & Results

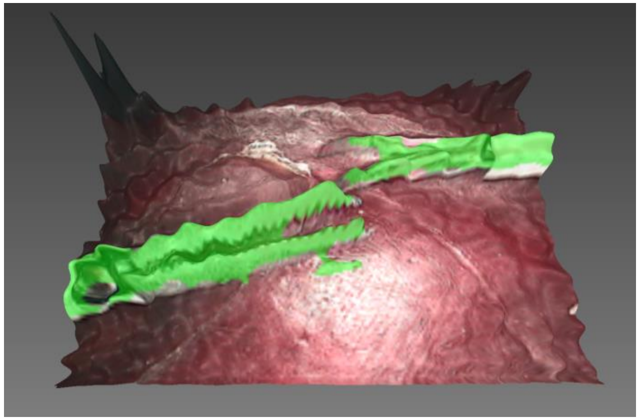




Experiments & Results



Input Data | ToF Mask | RGB Mask | Final Mask



- Improve the Super-Resolution framework
- Consider more complex segmentation techniques (e.g. k-means ..)

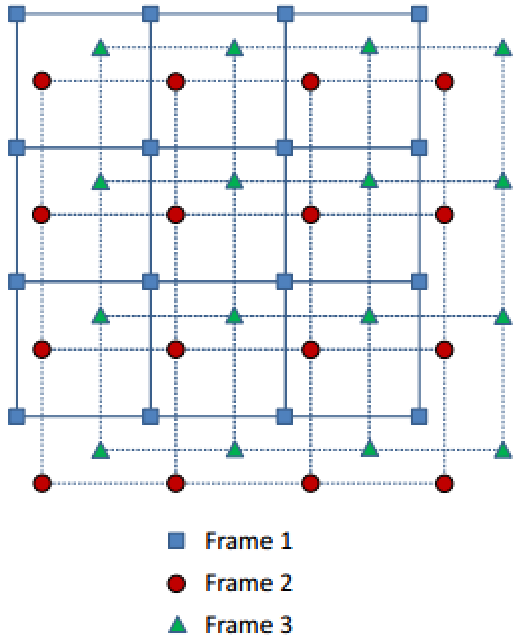
Thank you

THE RANGE IMAGING TOOLKIT

GSISH TUM
Graduate School of
Information Science
in Health

Multi-frame Super-Resolution

- Simultaneously increase image quality and spatial resolution
- Exploit small movements of the sensor



1. Register all images
2. Set up a generative image model

$$\boldsymbol{y}^{(k)} = \boldsymbol{W}^{(k)}\boldsymbol{x} + \epsilon^{(k)}$$

$\boldsymbol{W}^{(k)}$: System matrix of the k^{th} frame

3. Solve the equation system

$$\hat{\boldsymbol{x}}_{MAP} = \arg\min_{\boldsymbol{x}} \sum_{k=1}^{K} \left\| \boldsymbol{y}^{(k)} - \boldsymbol{W}^{(k)}\boldsymbol{x} \right\|_2^2 + \lambda R(\boldsymbol{x})$$