Hybrid 3-D Endoscopy
The best of both worlds

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Pattern Recognition Lab (CS 5)

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TECHNISCHE FAKULTÄT

Outline

- Minimally Invasive Procedures
- Time-of-Flight Technology
- Intrinsic/Extrinsic Calibration
- Hybrid Preprocessing
- First Medical Applications

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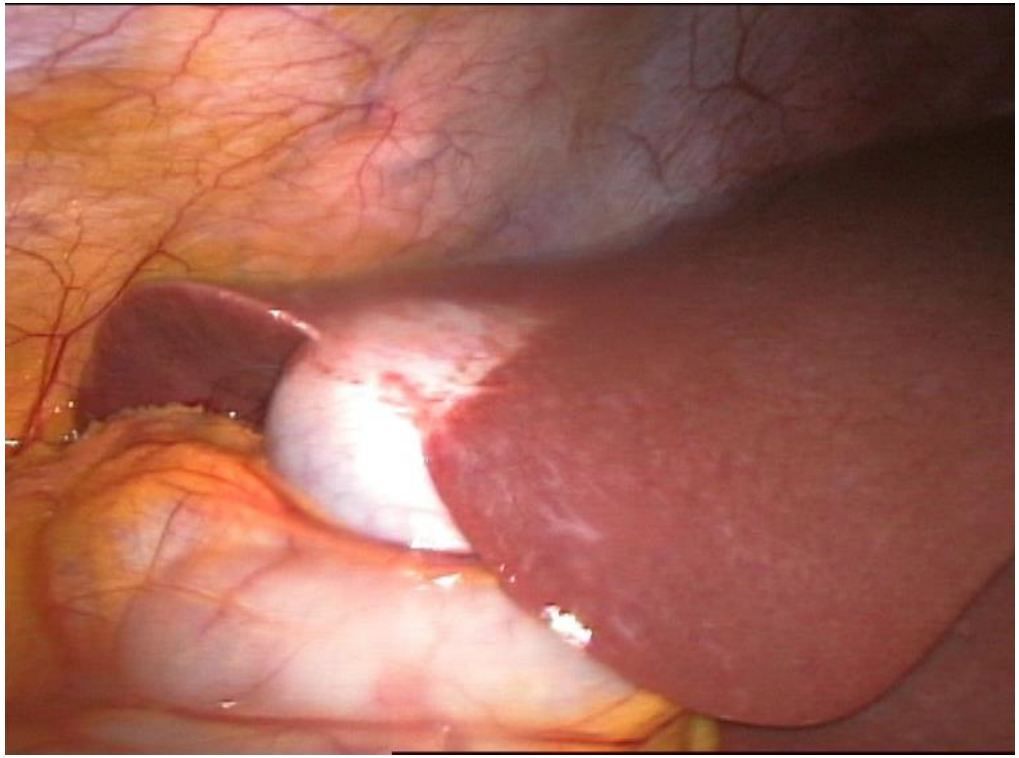
Motivation

Drawbacks:

- Narrow field of view
- Lack of orientation
- Lack of intuitive navigation



wikipedia.org

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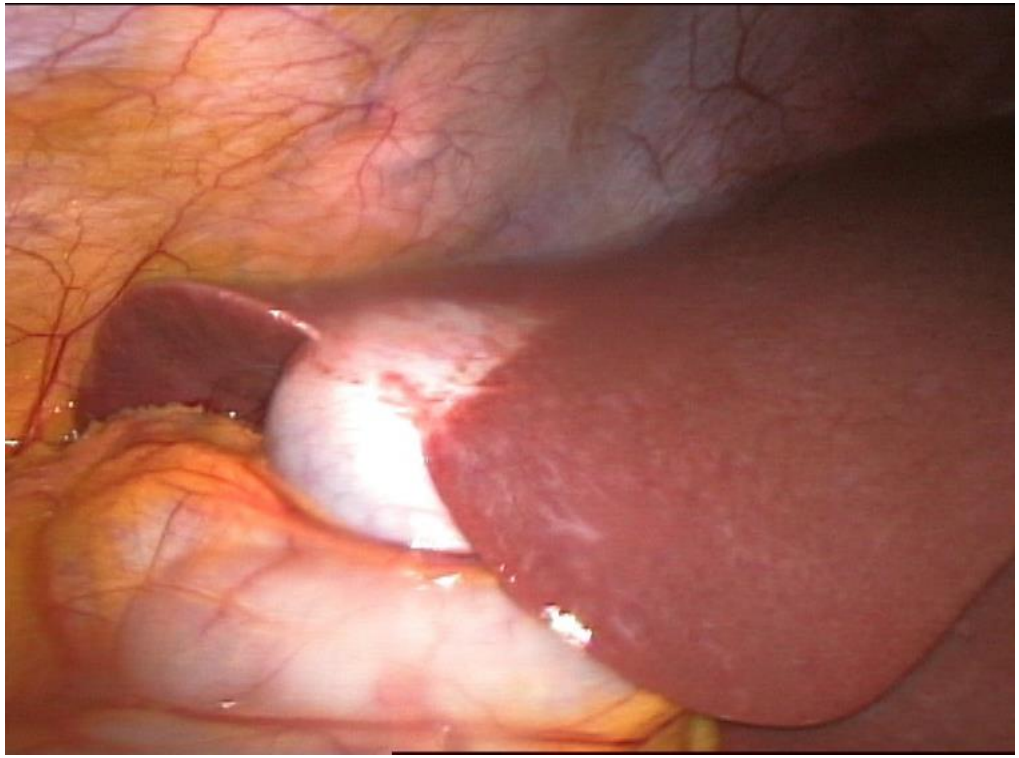
Augment color data with metric range data



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Time-of-Flight Devices

	CamCube 3	Camboard Nano	DS325
Resolution [px]	200×200	160×120	320×240
Frame rate [Hz]	40	90	60
Range [cm]	30-700	5-50	10-100
FoV [°]	40×40	90×68	74×58
Noise level [mm]	± 6	± 10	± 10
Price [€]	~8000	~500	~180

Time-of-Flight Technology

Why Time-of-Flight:

- Very cheap to manufacture
- Independent of texture information
- Constant spatial resolution

Drawback:

- Low resolution
- Low signal-to-noise ratio

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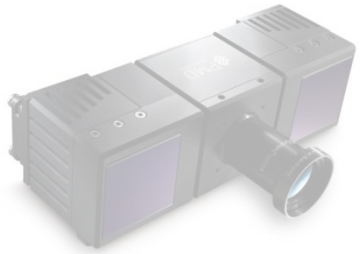
Approach:

- Hybrid Time-of-Flight/RGB Imaging



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Intrinsic/Extrinsic Calibration

Challenge for Time-of-Flight:

- Inhomogeneous illumination
- Very low resolution

→ Automatic detection algorithms fail

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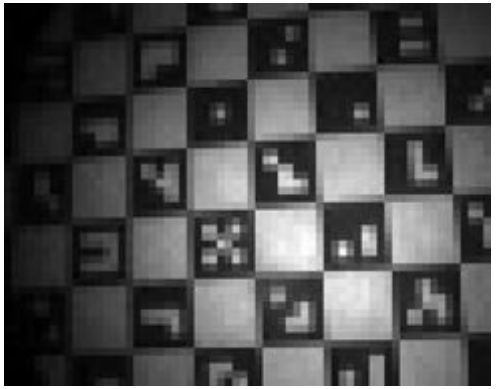
Approach:

- Preprocessing required
- Embedded barcodes

→ Automatic detection & many corners visible



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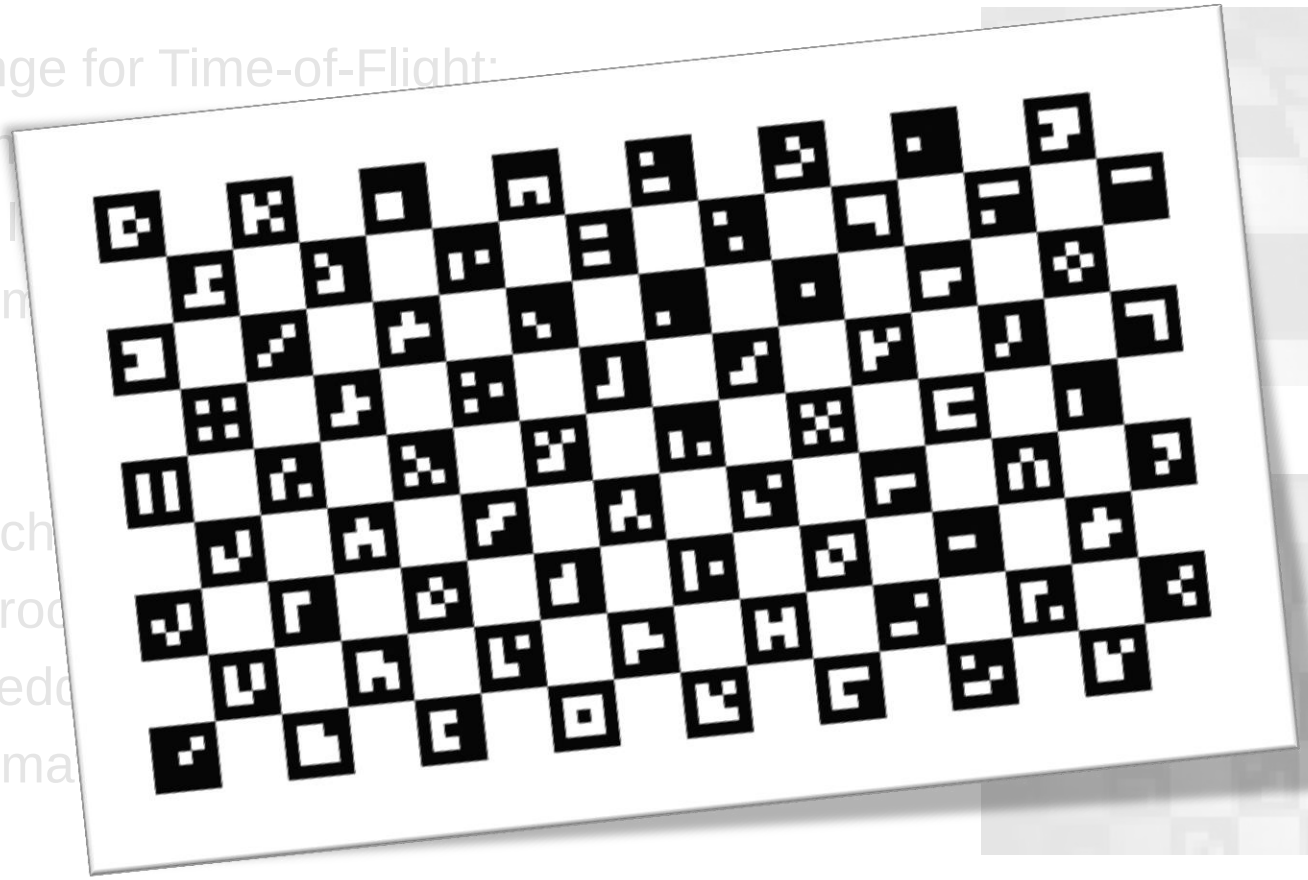
→ Autom

Approach

- Preproc
- Embedd

→ Automa



Intrinsic/Extrinsic Calibration

Challenge

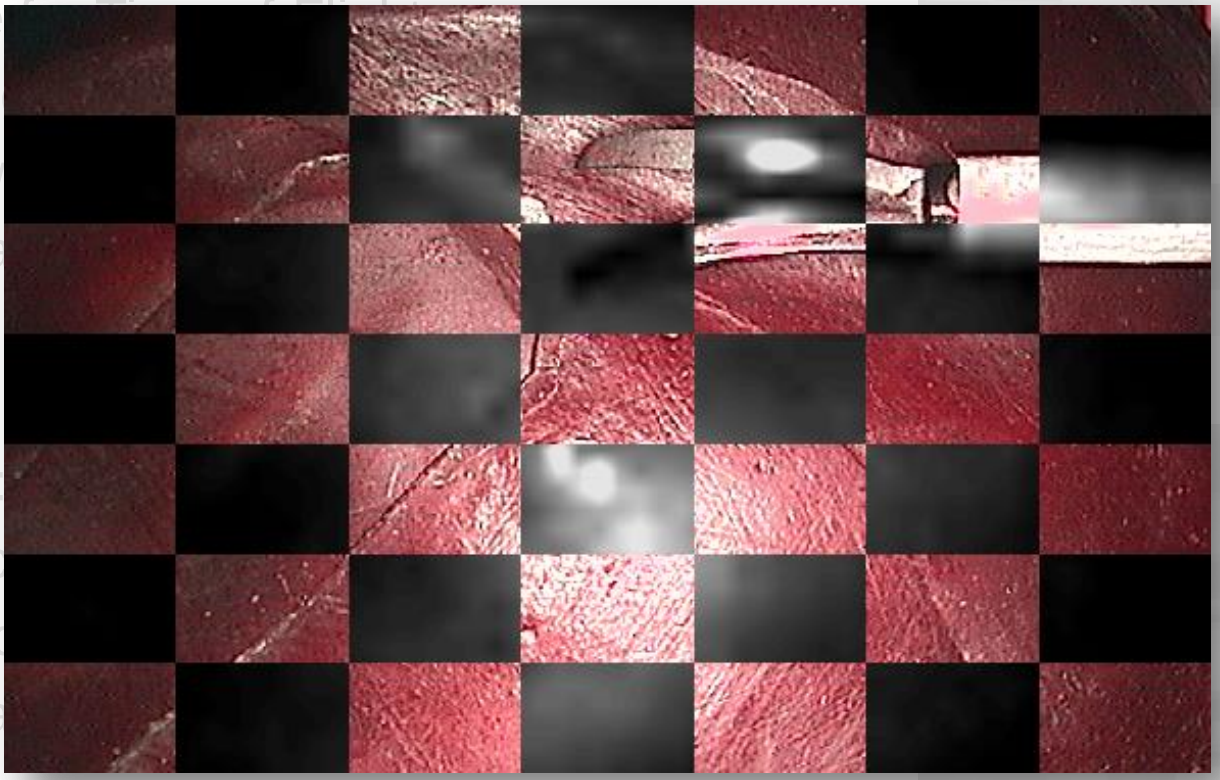
- Inhomo
- Very lo

→ Automa

Approach

- Preproc
- Embed

→ Automa



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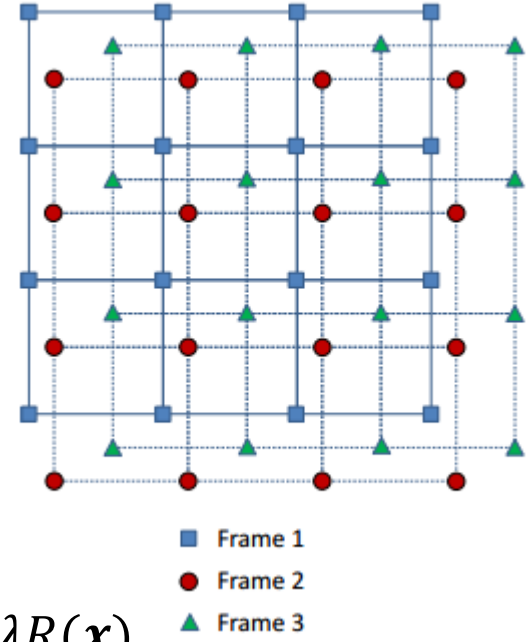
Hybrid Super-Resolution

- 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

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

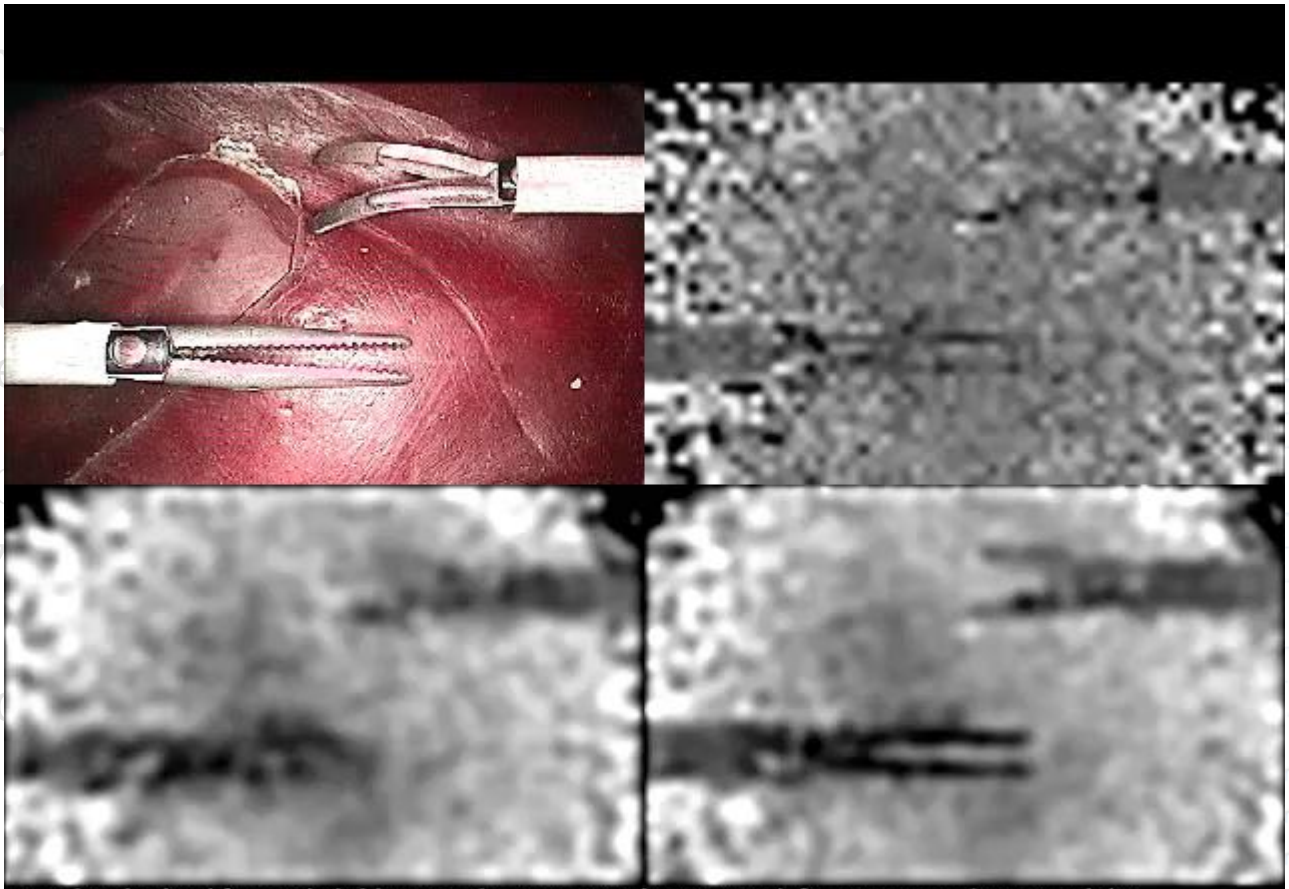
Hybrid Super-Resolution

- Sim… …on
- Exp…

1. R…
2. S…

y…
w…

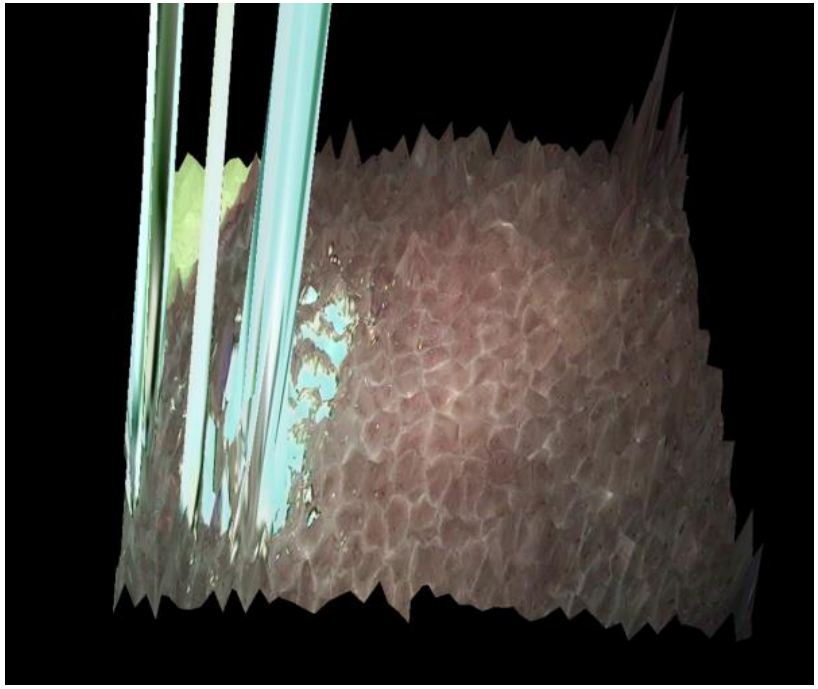
3. S…

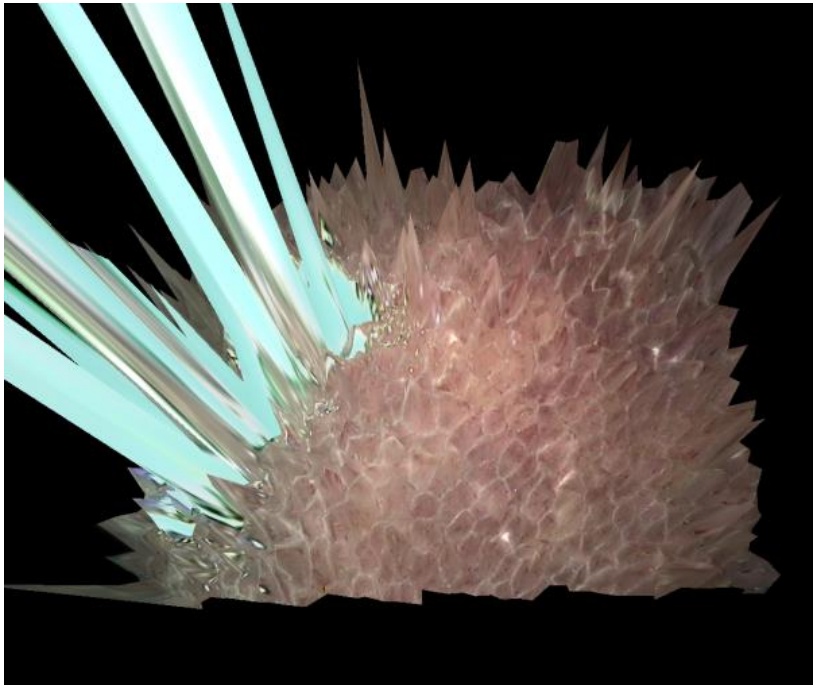


Results obtained from a hybrid 3-D endoscope: RGB image (top left), raw range data (top right), single-sensor super-resolution (bottom left), our proposed multi-sensor approach (bottom right)

…ame 1
…ame 2
…ame 3

Removal of Specular Reflections





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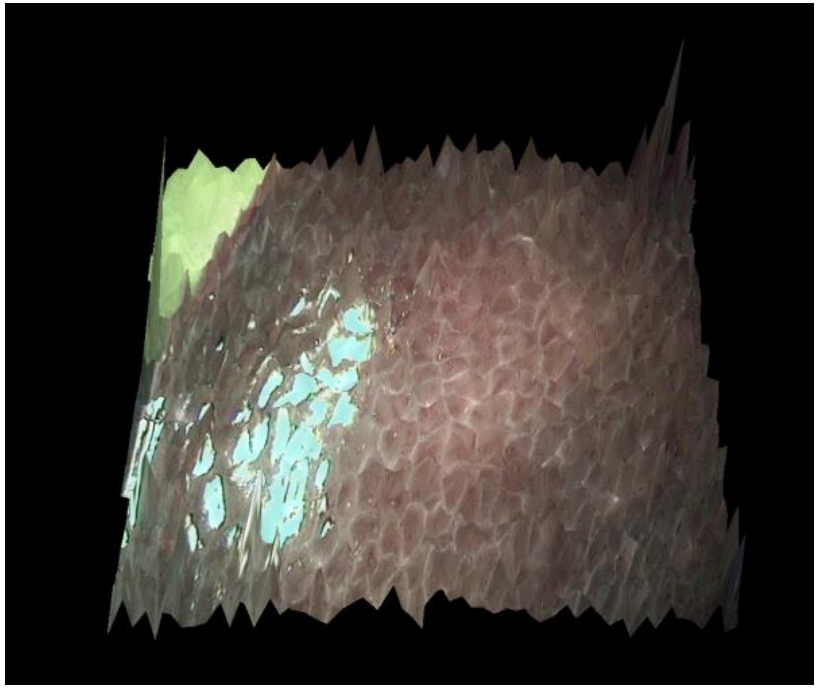
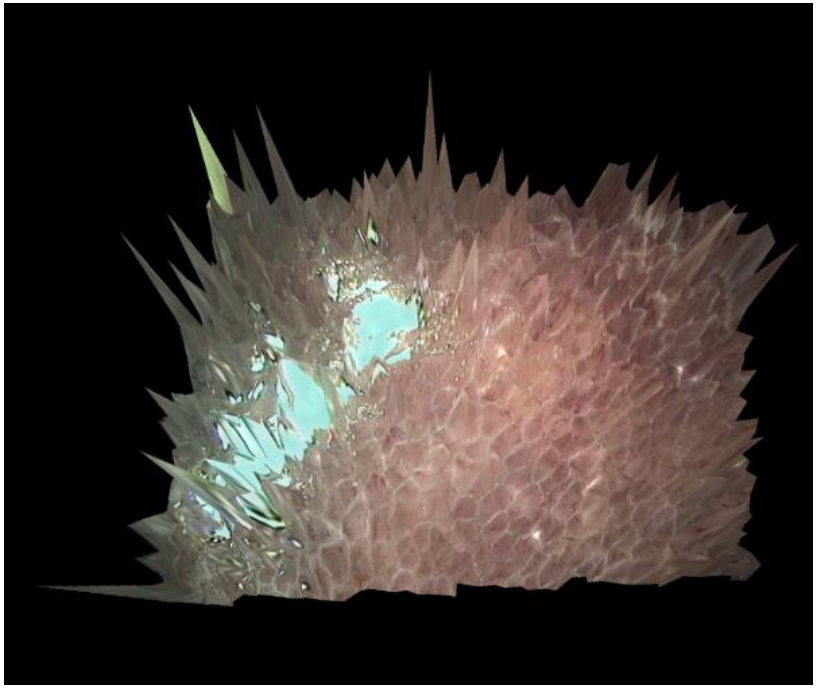
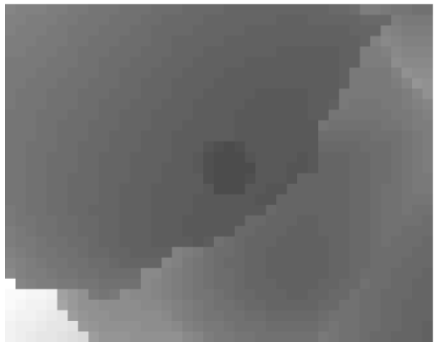


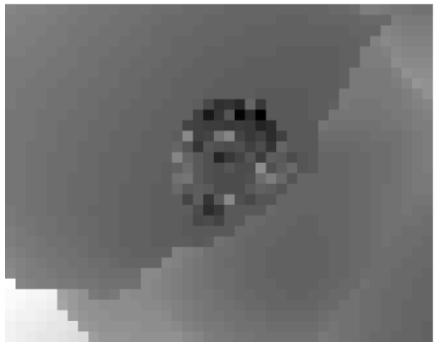


Removal of Specular Reflections

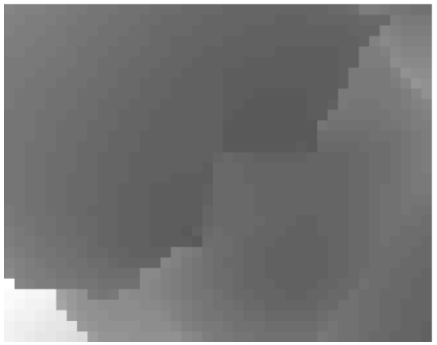
1. Exploit two different perspectives
2. Detect all specular reflections
3. Calculate 2-D features in both images (SURF)
4. Estimate patch wise for each Reflection an affine transformation
5. Replace the specular regions in one image by non specular regions of the other



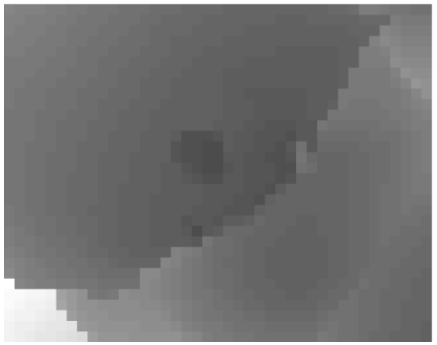
Ground truth



Raw data



Interpolation



Out approach

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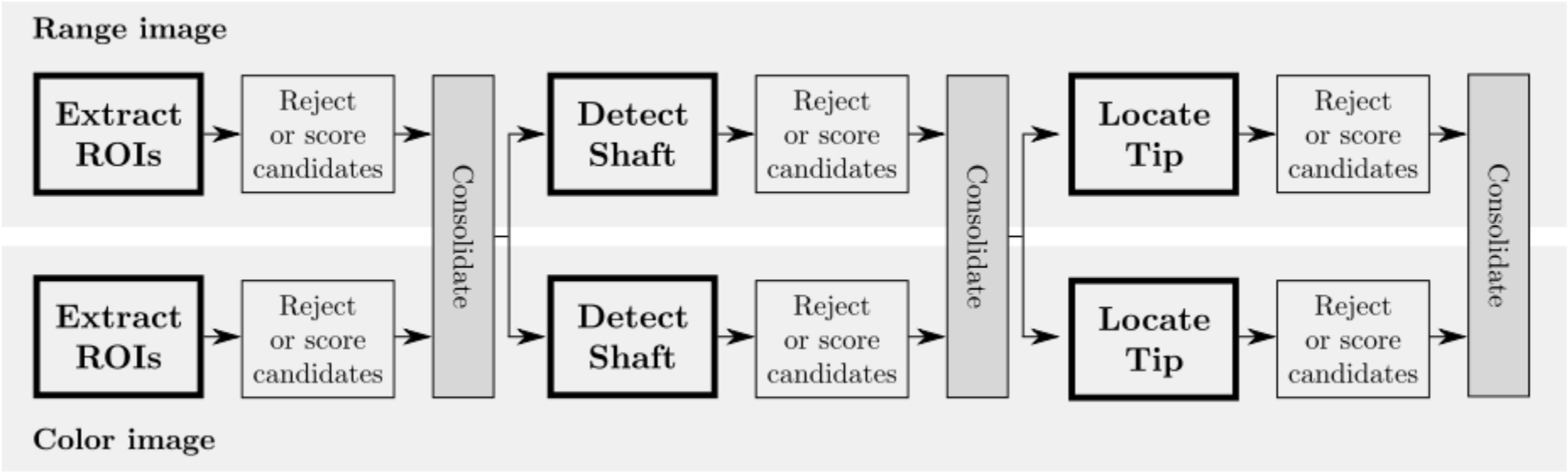
Tool Localization

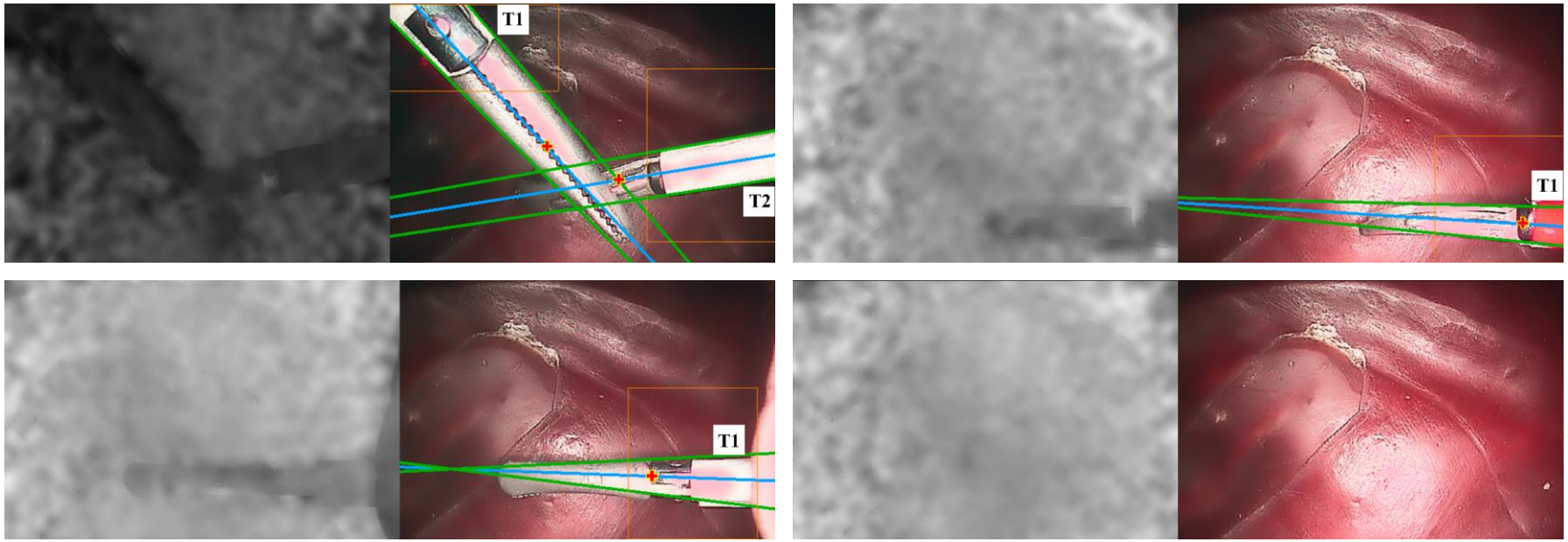
- Robust algorithm using color and range information[5]
- Based on a Hough transformation we locate the tool tip in 3-D

[5] “Laparoscopic Instrument Localization using a 3-D Time-of-Flight/RGB Endoscope”, WACV 2013, Haase et al.



Tool Localization

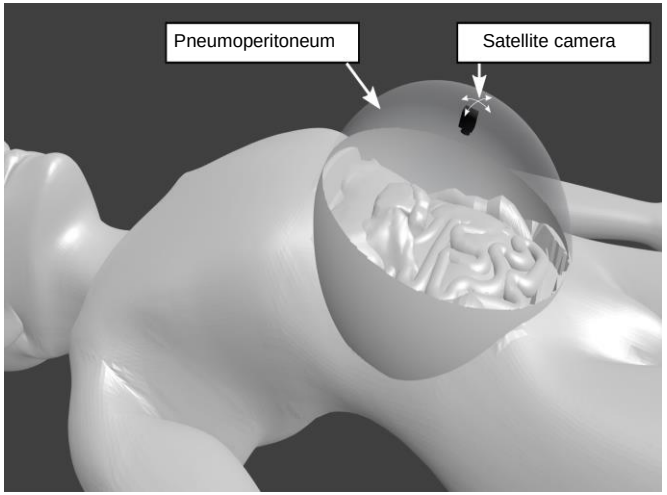
- Robust localization in challenging scenarios
- Intersection, Blood, Occlusion

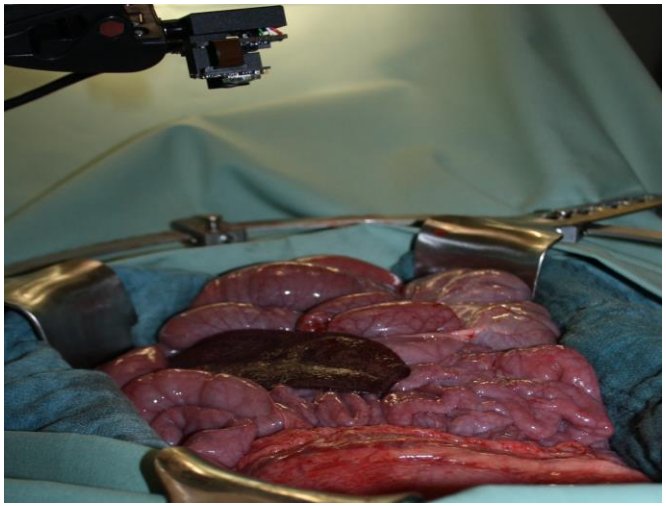


Situs Reconstruction (Time-of-Flight Satellite Cameras)

- Address the narrow field of view
- Fuse different views into a big reconstruction of the whole operation situs

→ Allow a better initial orientation within the human body





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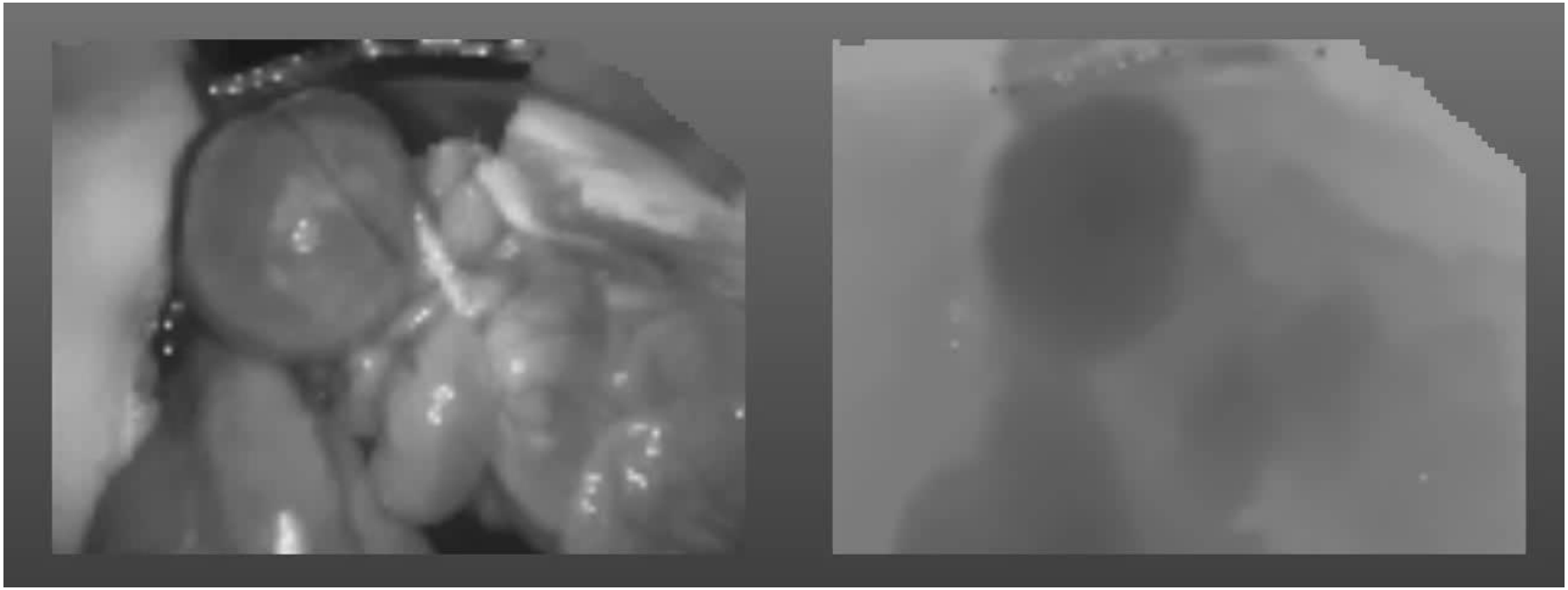

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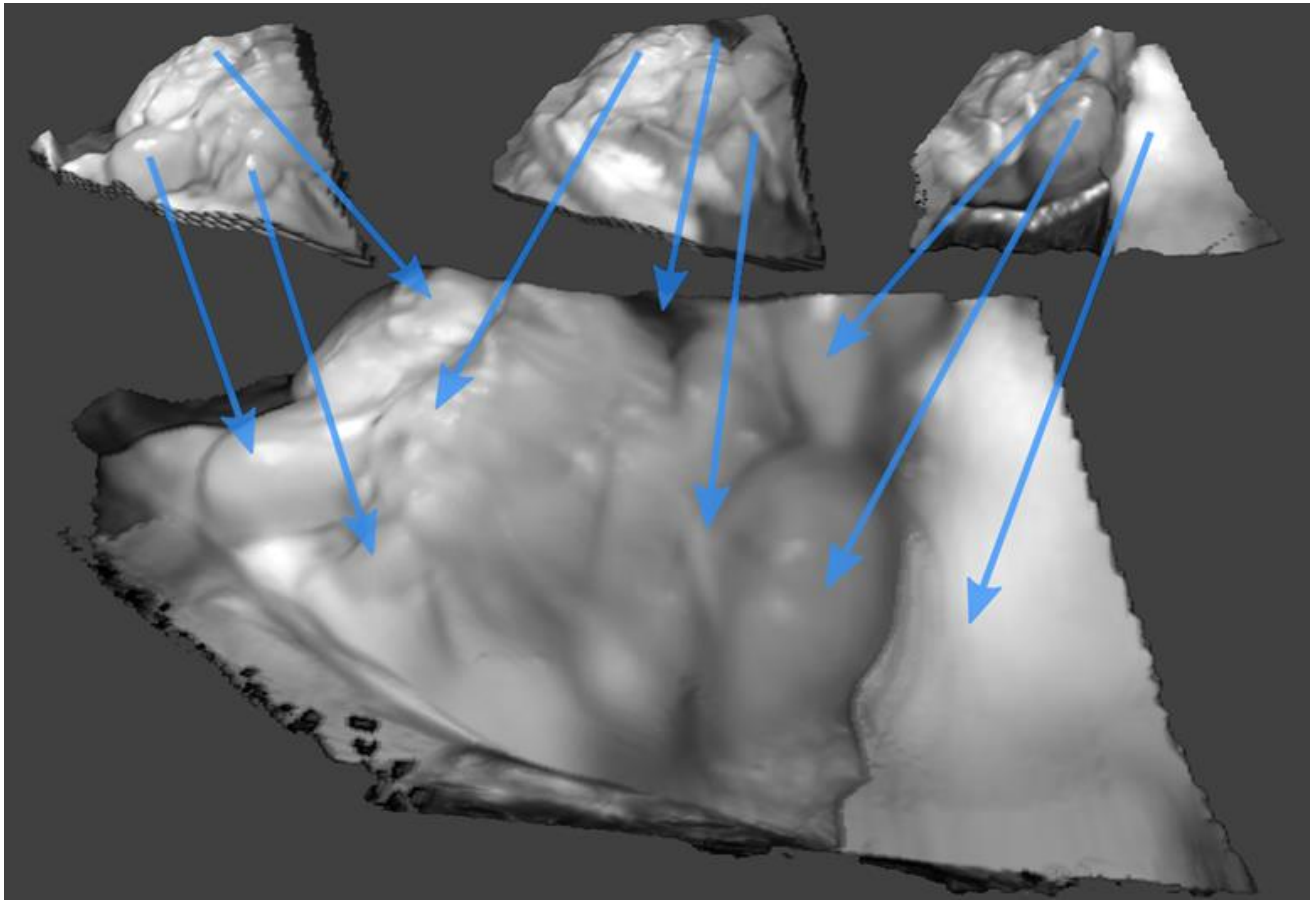

Thank you


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