



Real-scale 3D reconstruction from monocular endoscope images

Víctor M. Batlle, J.M.M. Montiel, Juan D. Tardós

Universidad de Zaragoza, Spain

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Universidad
Zaragoza

EndoMapper



Instituto Universitario de Investigación
en Ingeniería de Aragón
Universidad Zaragoza

Reconstruction Outside vs. Inside the human body

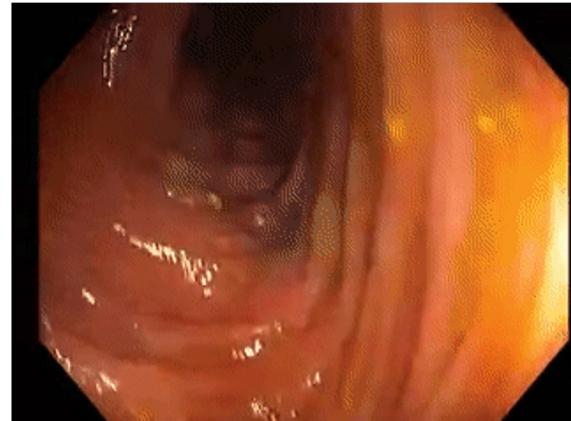
Outside

[KITTI (2013)]



Inside

[EndoMapper (2022)]



- Stereo images
- Monocular images
 - ⚠ Scale problem

[26] A. Geiger et al. (2013). *Vision meets Robotics: The KITTI Dataset*.
[25] P. Azagra et al. (2022). *EndoMapper dataset of complete calibrated endoscopy procedures*.

Reconstruction Outside vs. Inside the human body

Outside

[KITTI (2013)]



Inside

[EndoMapper (2022)]



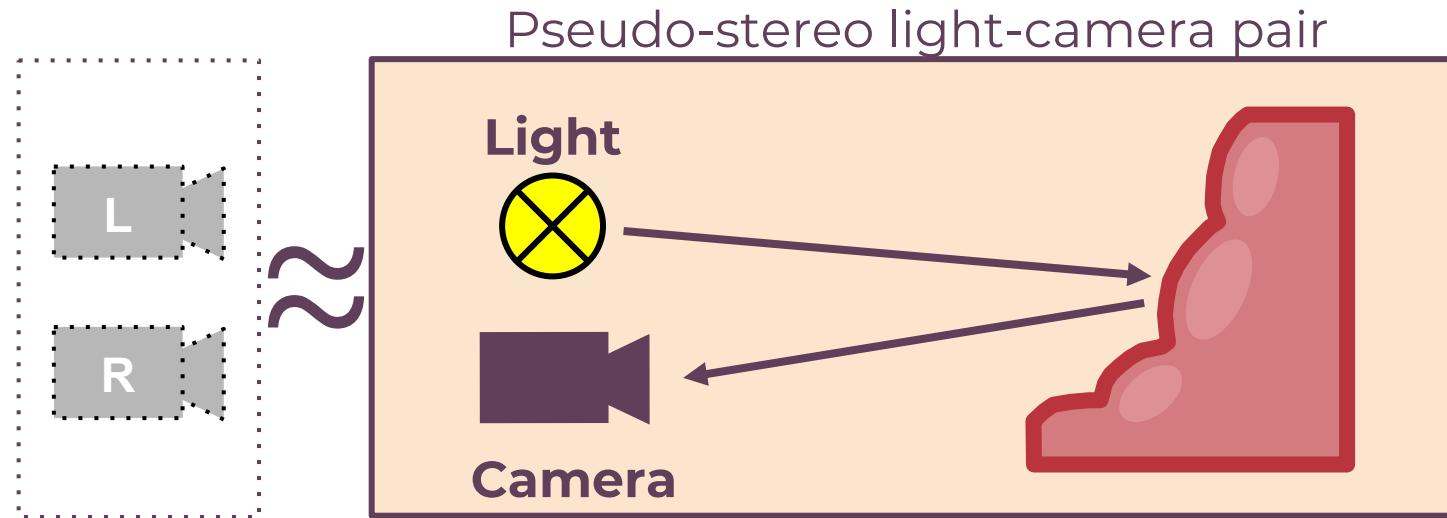
Previously, lighting changes were **dismissed**...

- Assuming **constant illumination**
- Using **invariant feature** points

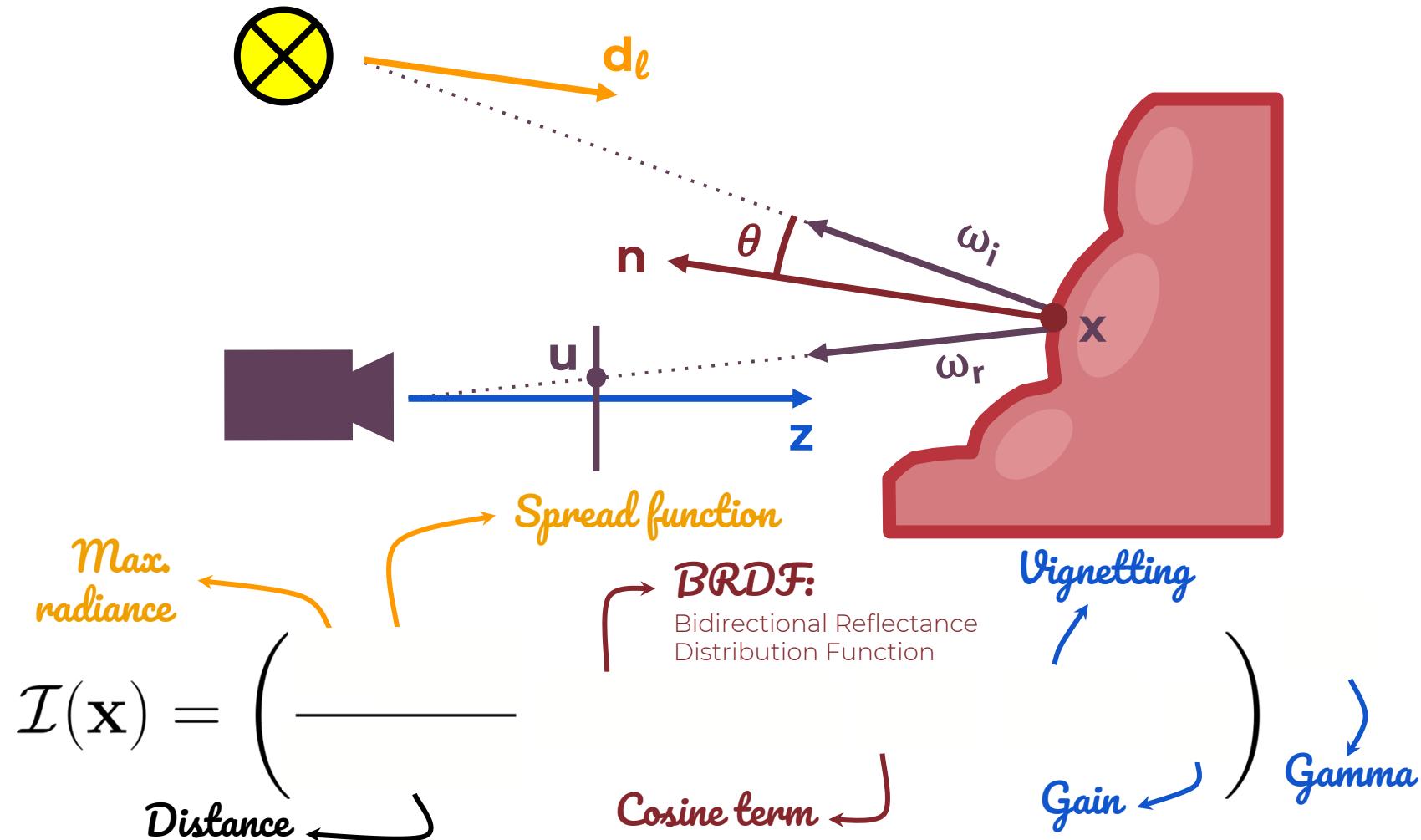
Our main goal:

Take profit of light changes

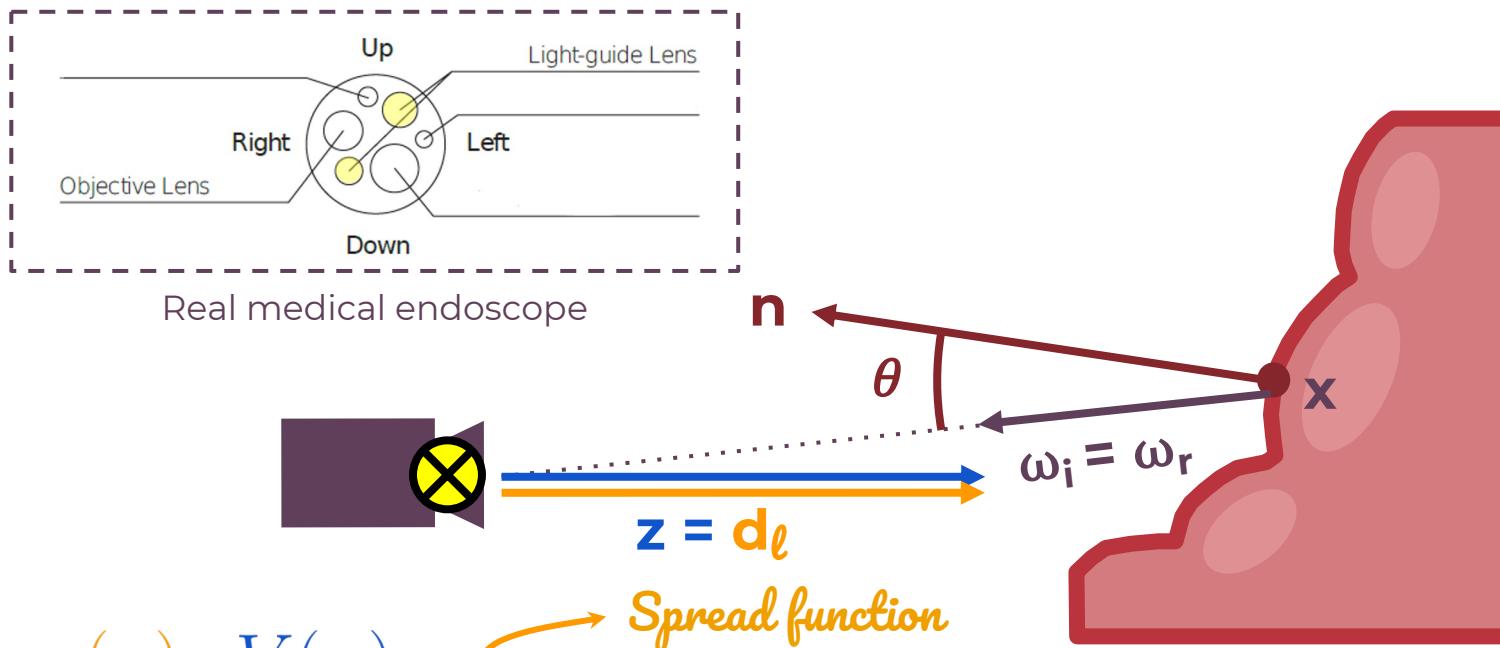
To get dense, **real-scale** reconstructions
from **monocular** sequences.



General photometric model



Simplification: light at optical center

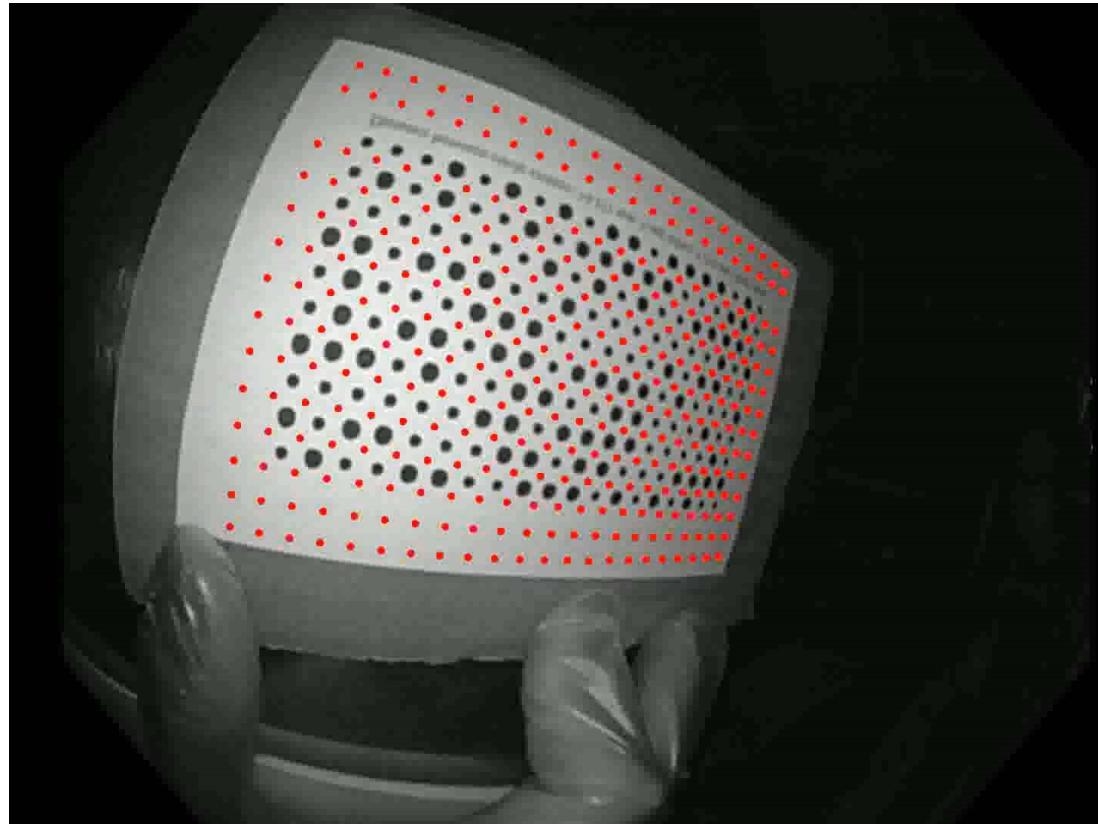


$$\mathcal{I}(x) = \left(\frac{\mu'(x)}{\|x - x_l\|^2} f_r(\theta) \cos \theta \right)^{1/\gamma}$$

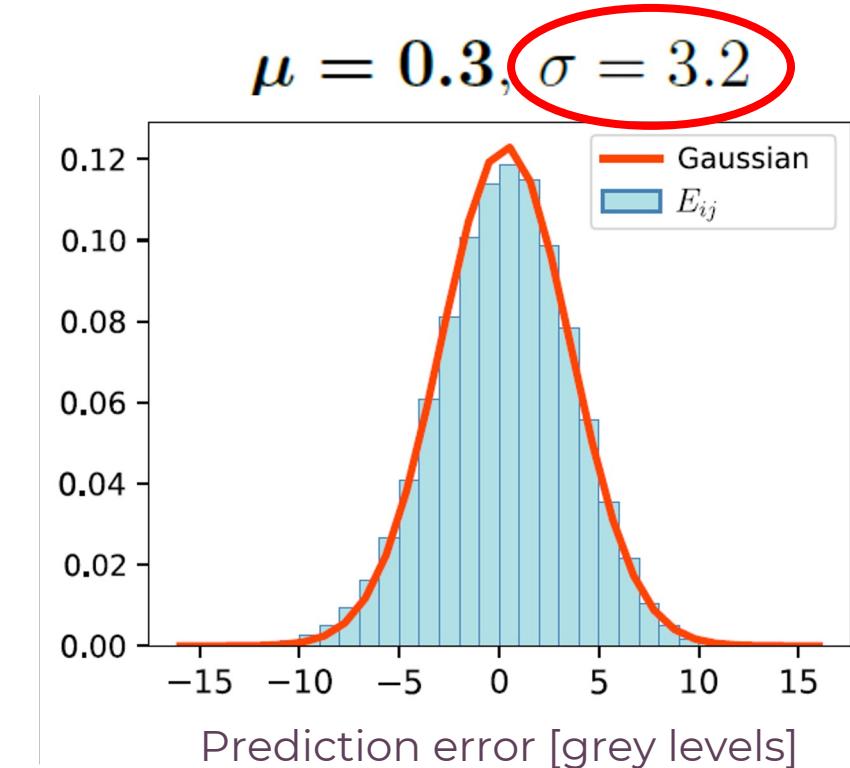
Annotations explain the components:

- $\mu(x) \cdot V(u)$: *Spread function*
- $\mu'(x)$: *Distance*
- $f_r(\theta)$: *BRDF: Bidirectional Reflectance Distribution Function*
- $\cos \theta$: *Cosine term*
- g_i : *Vignetting Gain*
- $1/\gamma$: *Gamma*

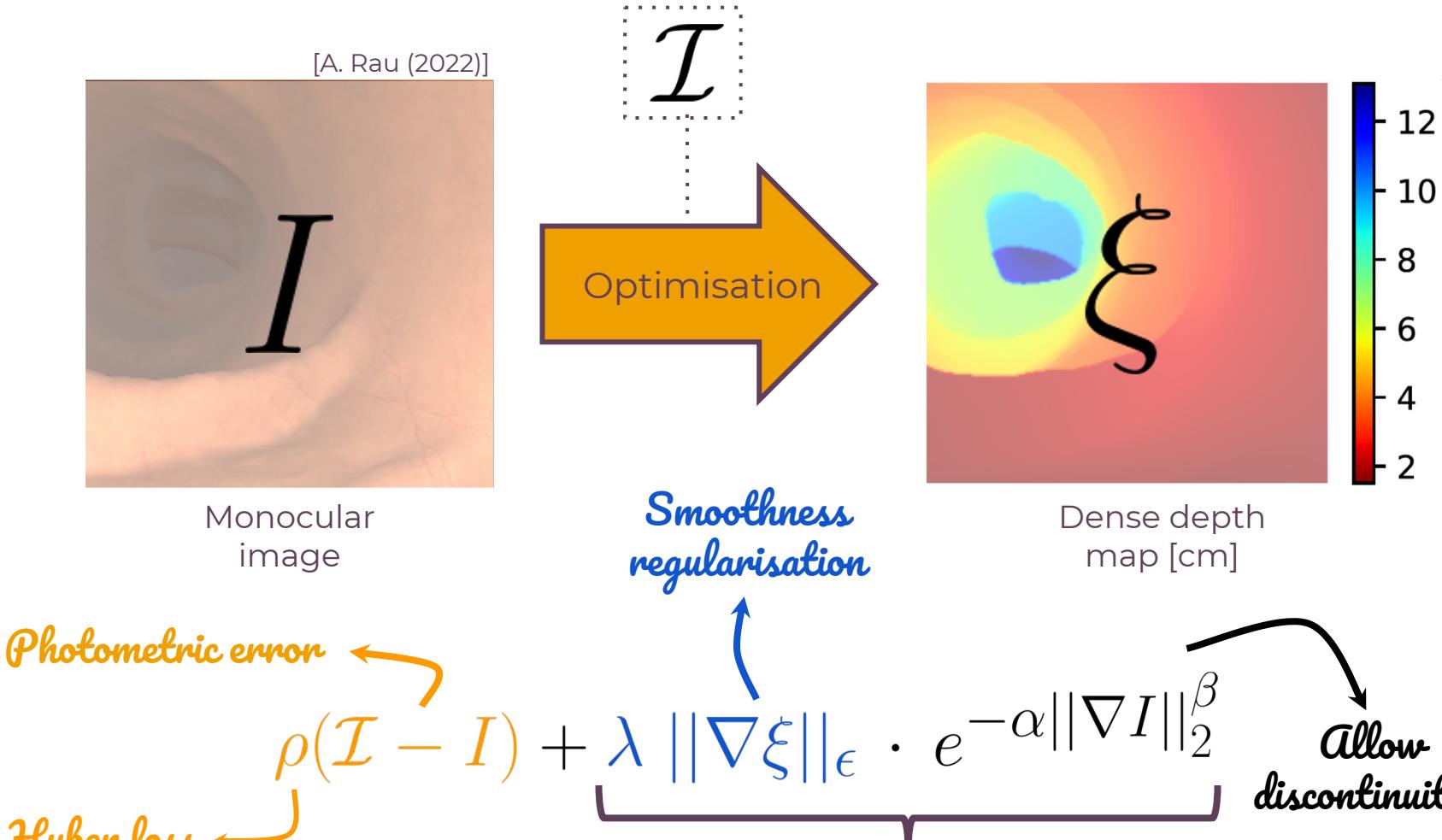
Endoscope calibration



[25] P. Azagra et al. (2022). *EndoMapper dataset of complete calibrated endoscopy procedures.*



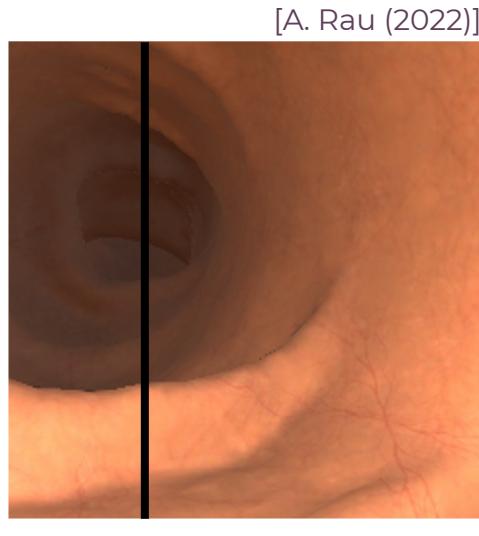
Depth estimation



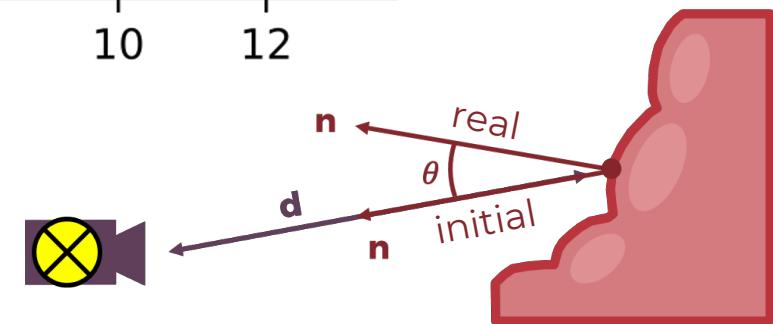
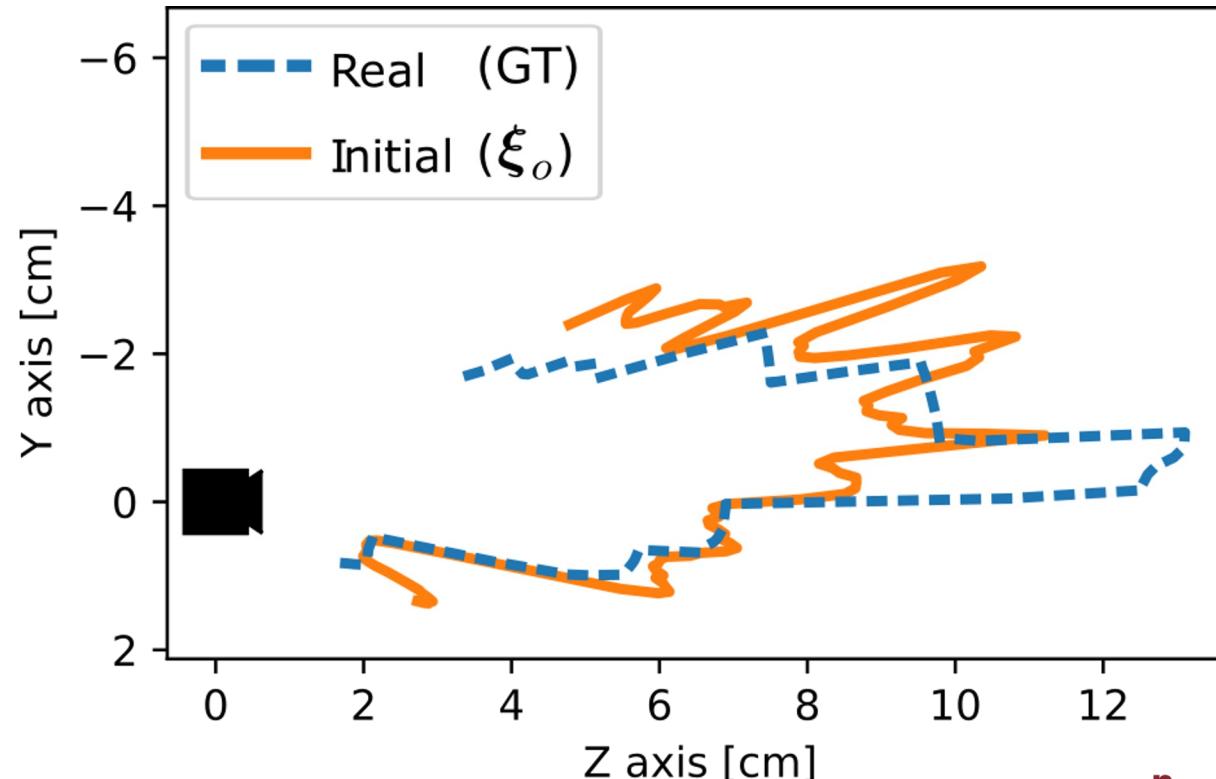
[10] R. A. Newcombe et al. (2011) *DTAM: Dense Tracking and Mapping in Real-Time*.

EXPERIMENTAL RESULTS

Simulated colon dataset

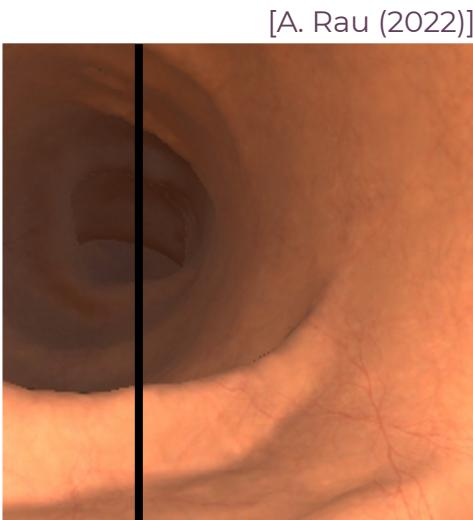


Synthetic
image

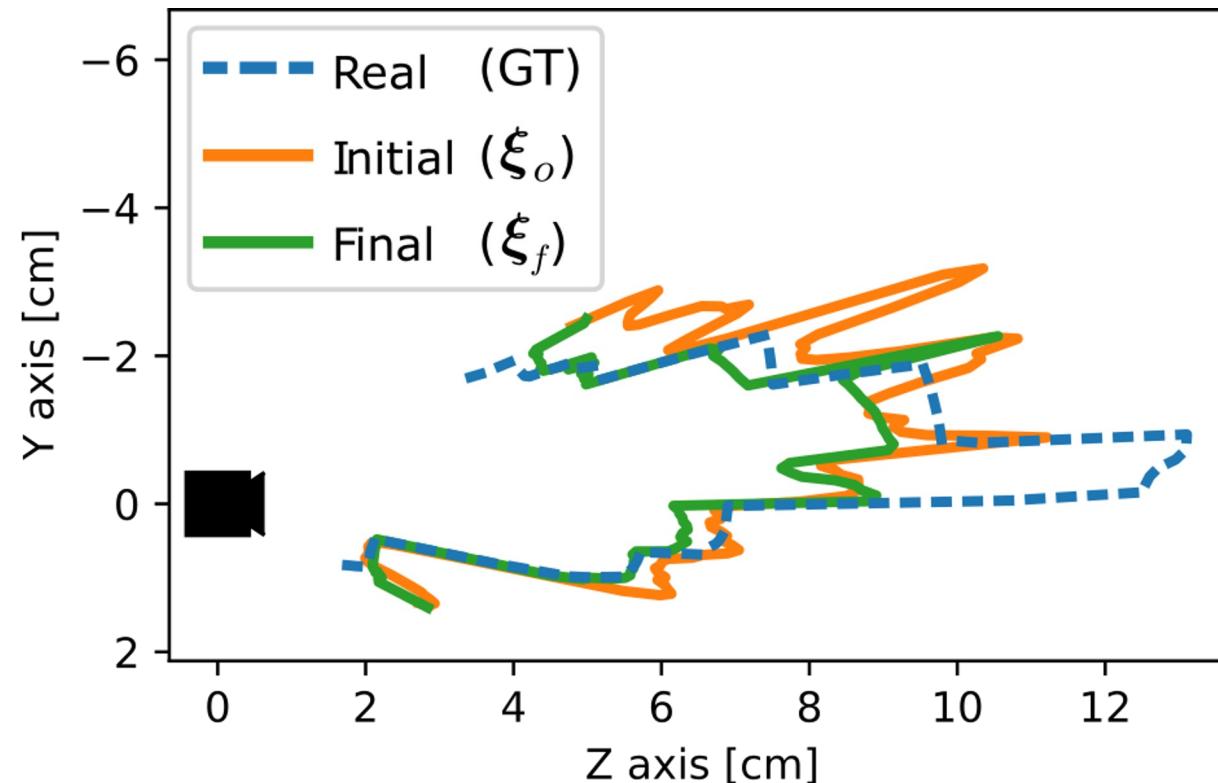


[24] A. Rau et al. (2022) *Bimodal camera pose prediction for endoscopy*.

Simulated colon dataset



Synthetic
image

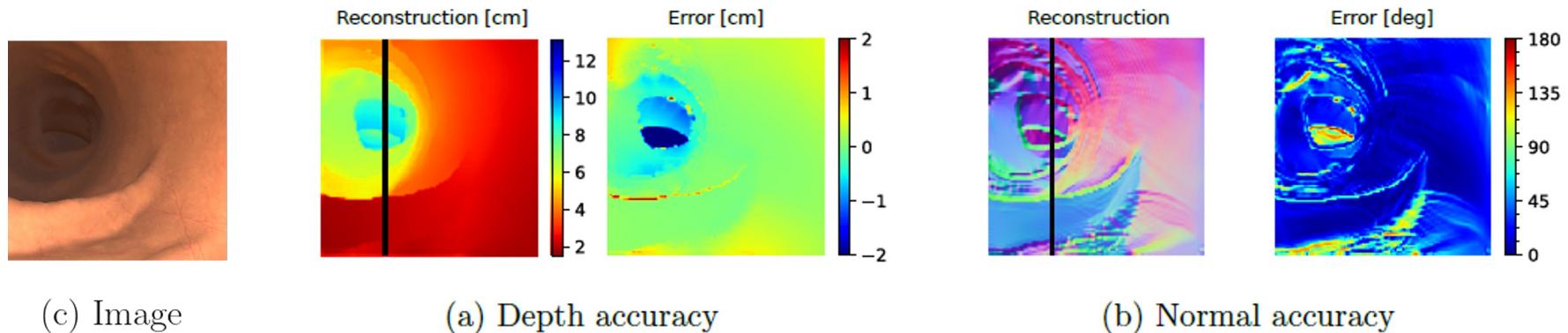


$$\rho(\mathcal{I} - I) + \lambda \|\nabla \xi\|_\epsilon \cdot e^{-\alpha \|\nabla I\|_2^\beta}$$

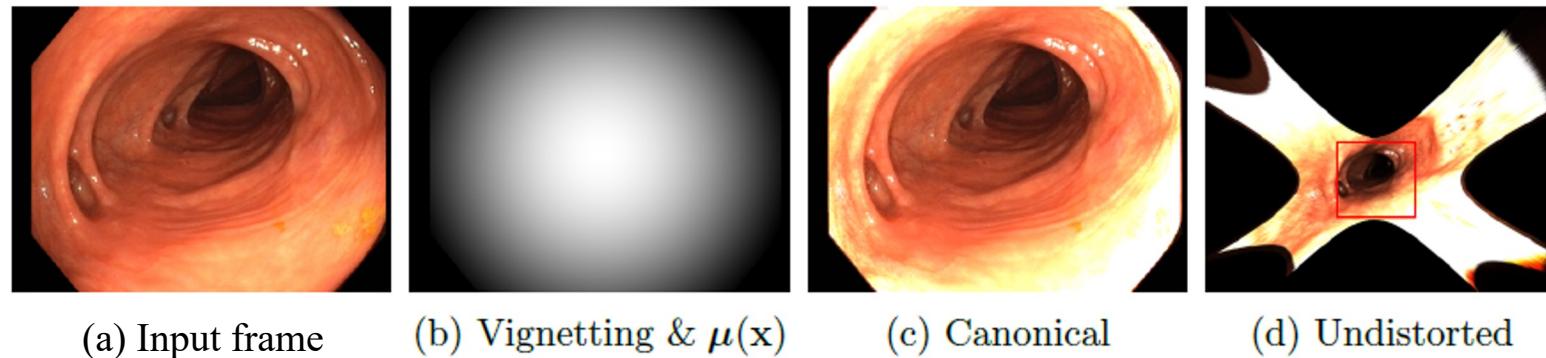
Simulated colon dataset

ξ	Reg.	# iter.	Depth error [cm]		Depth error [%]		Normals error [deg]	
			Mean	Median	Mean	Median	Mean	Median
$1/z$	∇	44 500	0.53	0.23	10.60	7.41	30.63	23.77
	∇^2	8 900	0.51	0.40	15.09	11.86	36.06	29.26
d	∇	20 000	0.33	0.16	7.90	4.98	26.21	18.75
	∇^2	44 500	0.38	0.20	9.57	6.37	32.00	23.56
$1/d$	∇	44 500	0.28	0.16	7.32	5.01	27.89	19.69
	∇^2	5 400	0.51	0.40	15.16	12.05	35.86	28.89

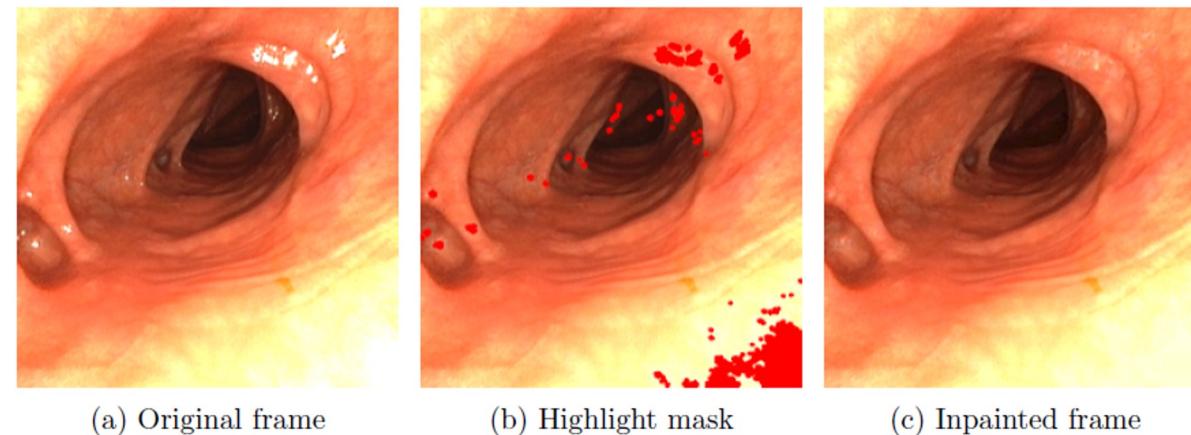
Table 5.2: Reconstruction accuracy on the simulated colon dataset.



Real colon dataset

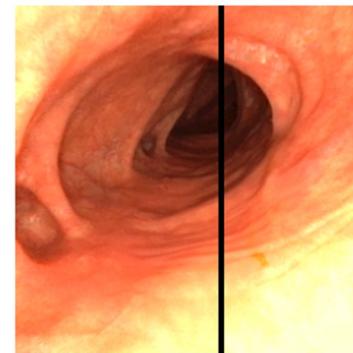


EndoMapper

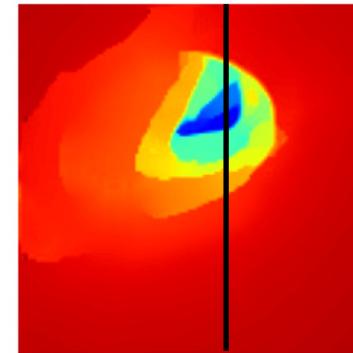


[25] P. Azagra et al. (2022). *EndoMapper dataset of complete calibrated endoscopy procedures*.

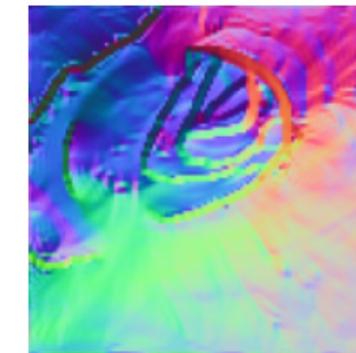
Real colon dataset



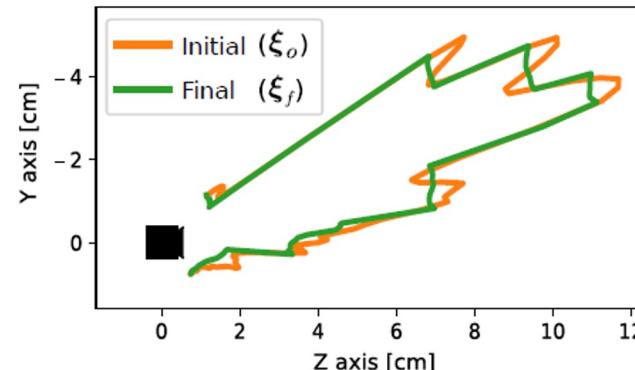
(a) Input frame



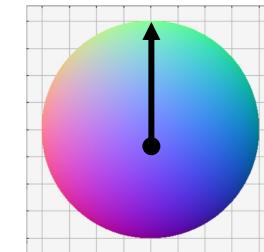
(b) Estimated depth

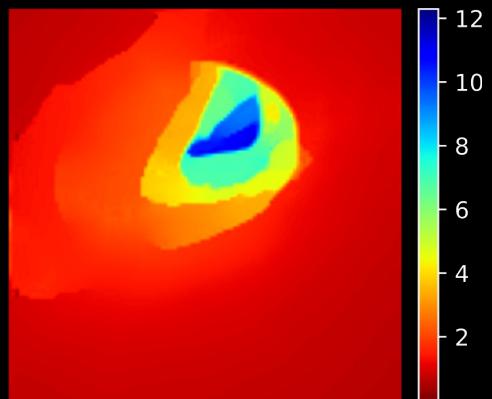
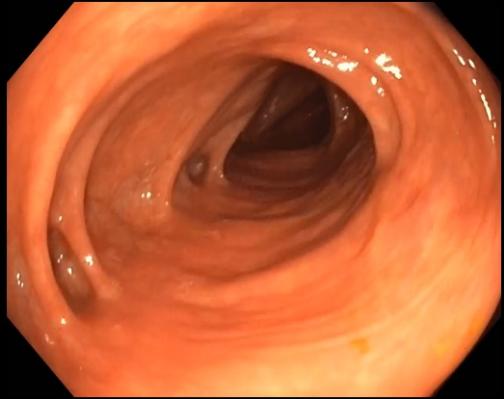


(c) Estimated normals

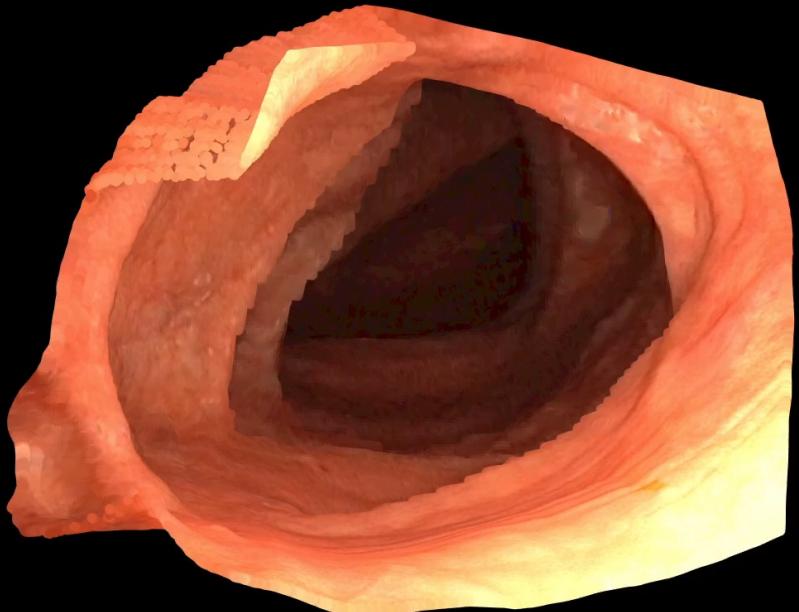


(d) Cross-section along black line





[25] Azagra, P et al. (2022).
*EndoMapper dataset of
complete calibrated
endoscopy procedures.*



(1) We can **reconstruct the 3D scene's real-scale** from monocular images.

*when surface BRDF and
camera gain are known.*

(2) Depth estimation with **7% error (3 mm).**

3D reconstruction