ROBOTICS
UNIVERSIDAD DE ZARAGOZA

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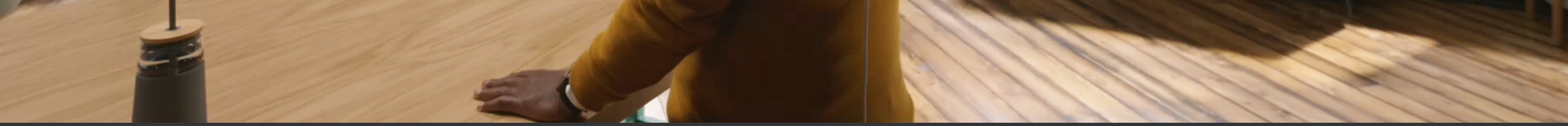


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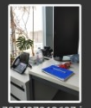
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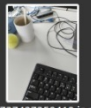
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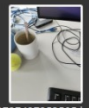
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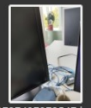
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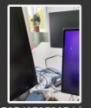
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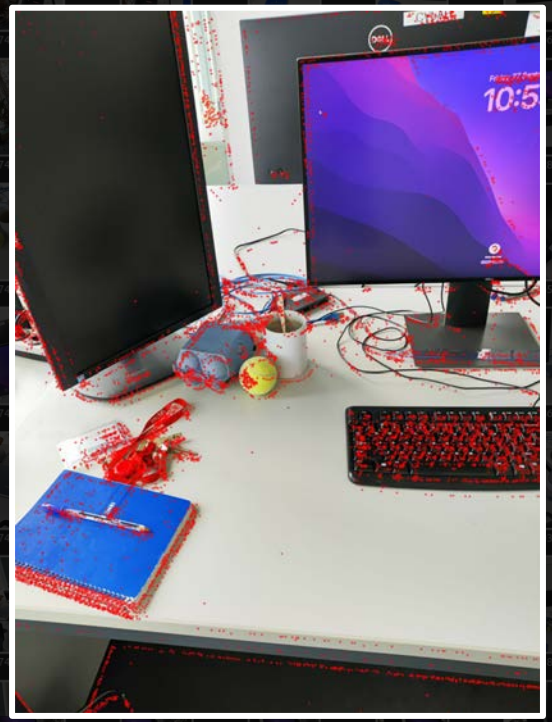

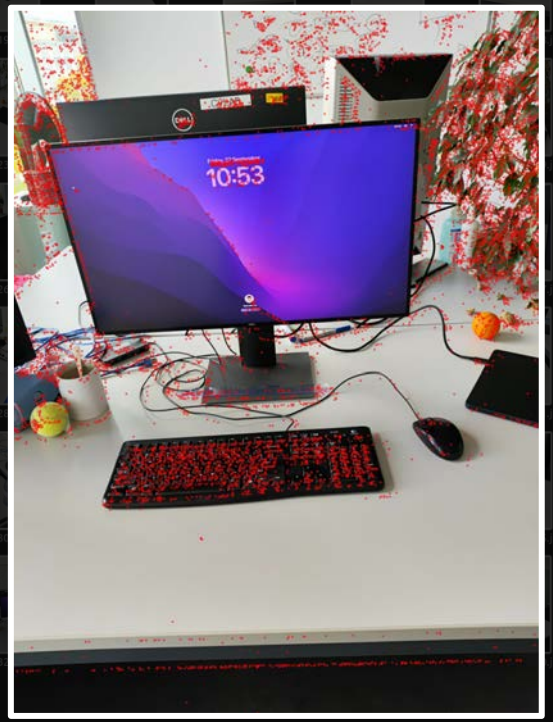
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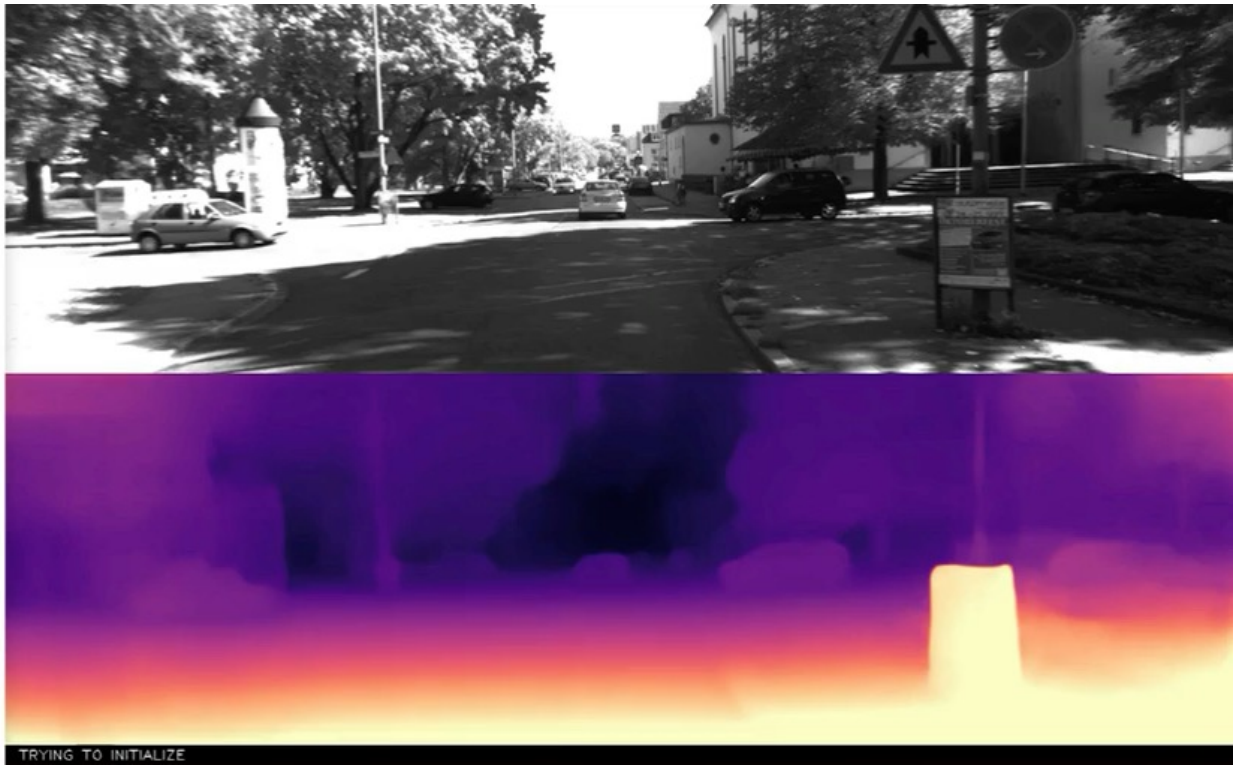
Reconstruction with COLMAP.
Schönberger et al. “Structure-from-Motion Revisited”. *CVPR (2016)*.

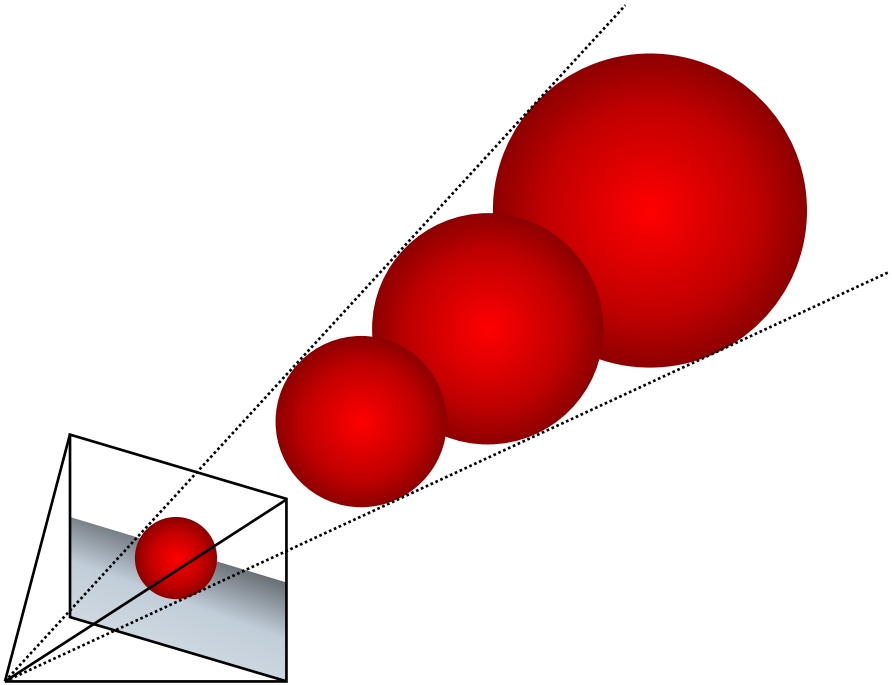

Road

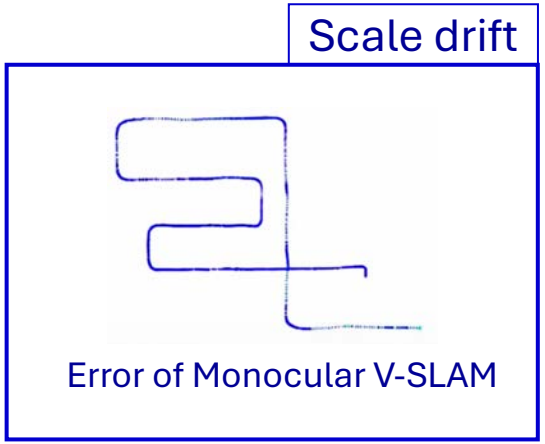
Image from Waymo. https://waymo.com/



Mur-Artal et al. “ORB-SLAM2: an Open-Source SLAM System for Monocular, Stereo and RGB-D Cameras”. *IEEE T-RO (2017).*
Batlle et al. “Scale estimation in monocular ORB-SLAM2 using deep convolutional networks”. *BSc Thesis, Universidad de Zaragoza (2020).*

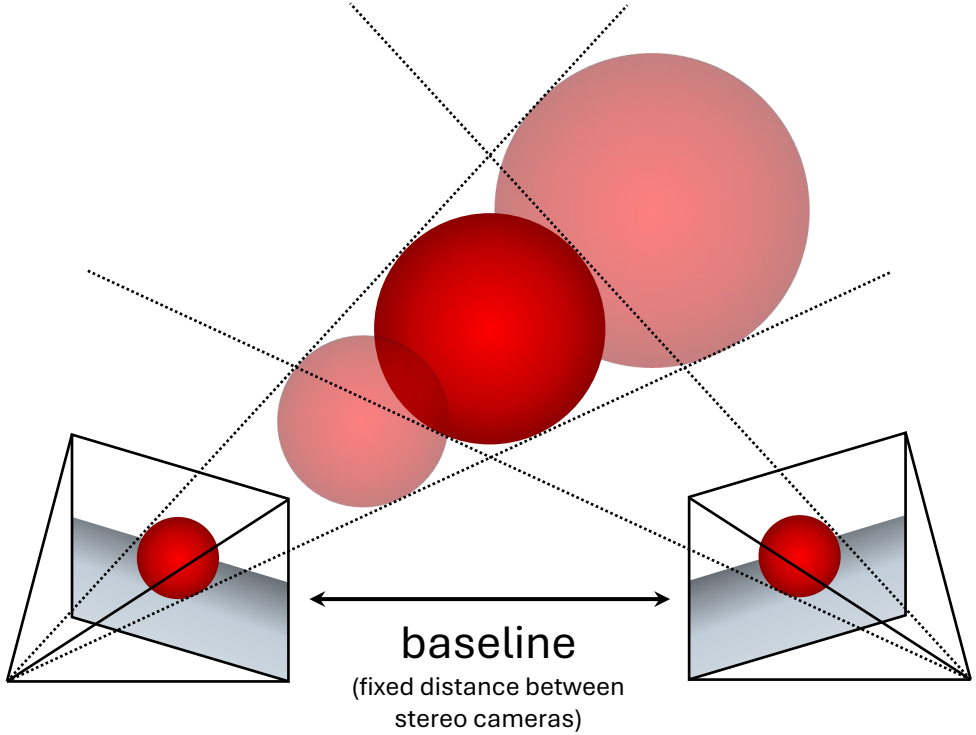
But monocular cameras cannot observe metric scale





Batlle et al. “Scale estimation in monocular ORB-SLAM2 using deep convolutional networks”. *BSc Thesis, Universidad de Zaragoza (2020).*

We integrate **monocular depth estimation** as an equivalent stereo system



Very data hungry.
Estimation is fixed.
Hard to adapt to OOD.

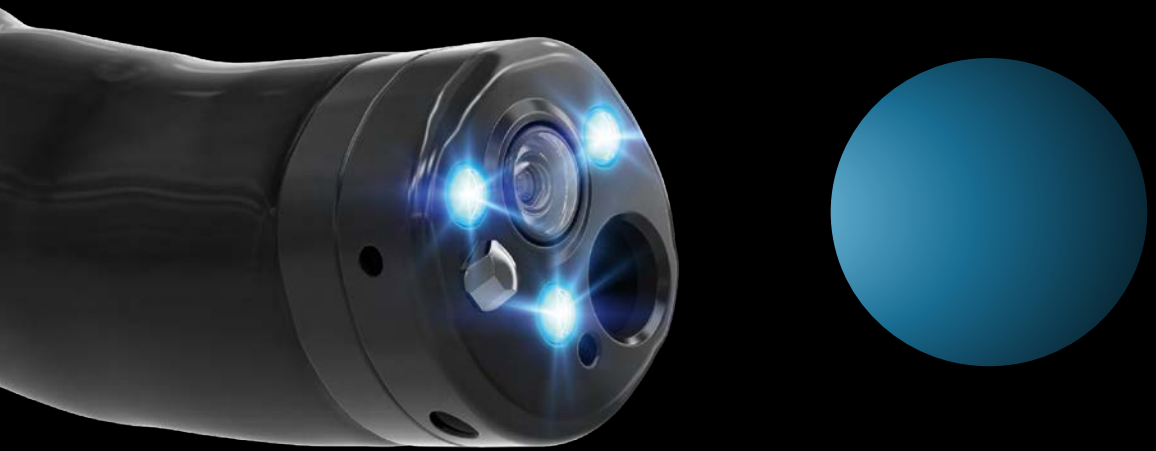
Dense
Texture less
Metric scale
Deformable reconstruction
Robust
Long-term
...


Body

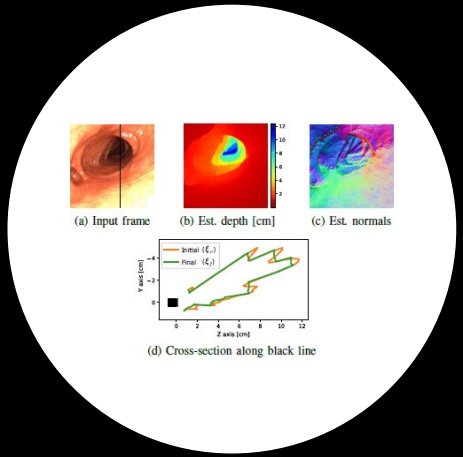
Constricted space.
Almost no data available.

One camera

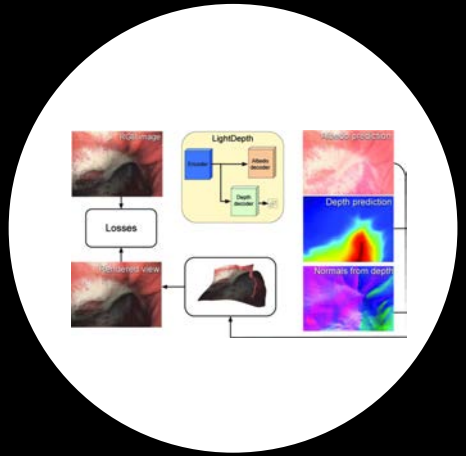
Three light sources



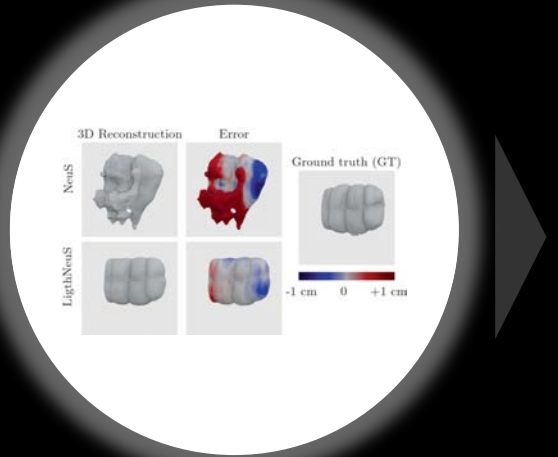
$$I \propto \frac{1}{d^2}$$



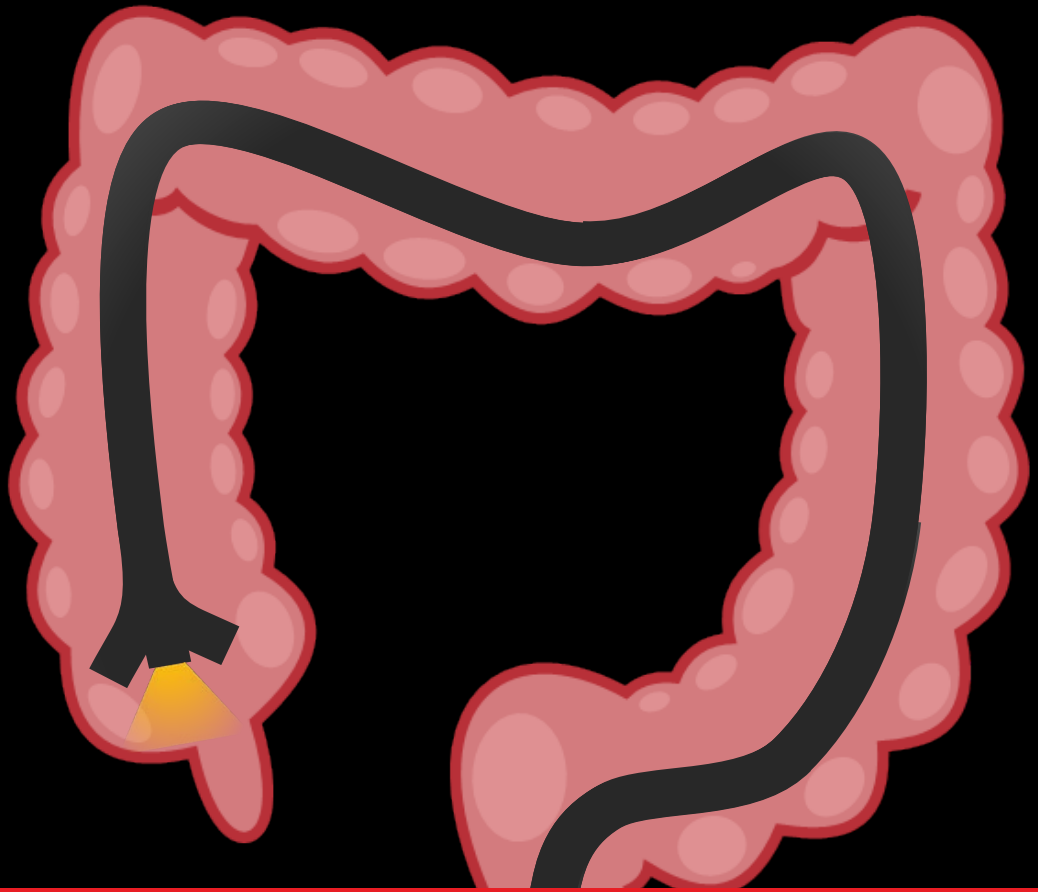
Photometric single-view dense 3D reconstruction in endoscopy.

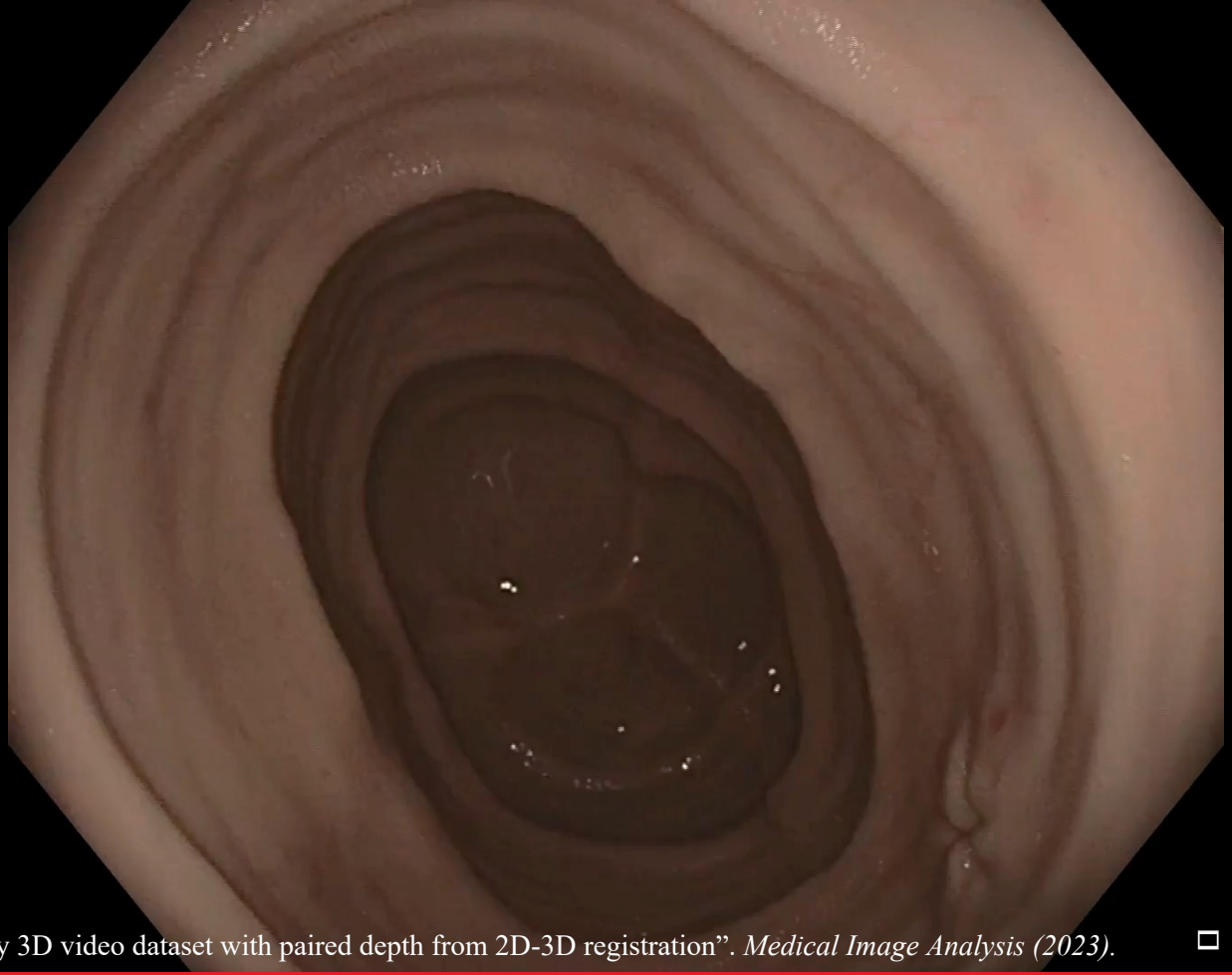


LightDepth: Single-View Depth Self-Supervision from Illumination Decline.



LightNeuS: Neural Surface Reconstruction in Endoscopy Using Illumination Decline.





Bobrow et al. “Colonoscopy 3D video dataset with paired depth from 2D-3D registration”. *Medical Image Analysis (2023).*

Illumination decline as depth cue

Light source properties

Camera properties

$$\mathcal{I}(\mathbf{x}) = \left(\frac{L_e}{d^2} \right) \mathrm{BRDF}(\mathbf{x}, \mathbf{d}) \cos(\theta) \left(g \right)^{1/\gamma}$$

Inverse-square law

Surface properties

Batlle et al. “LightNeuS: Neural Surface Reconstruction in Endoscopy Using Illumination Decline”. *MICCAI (2023).*

Calibrating camera and light source

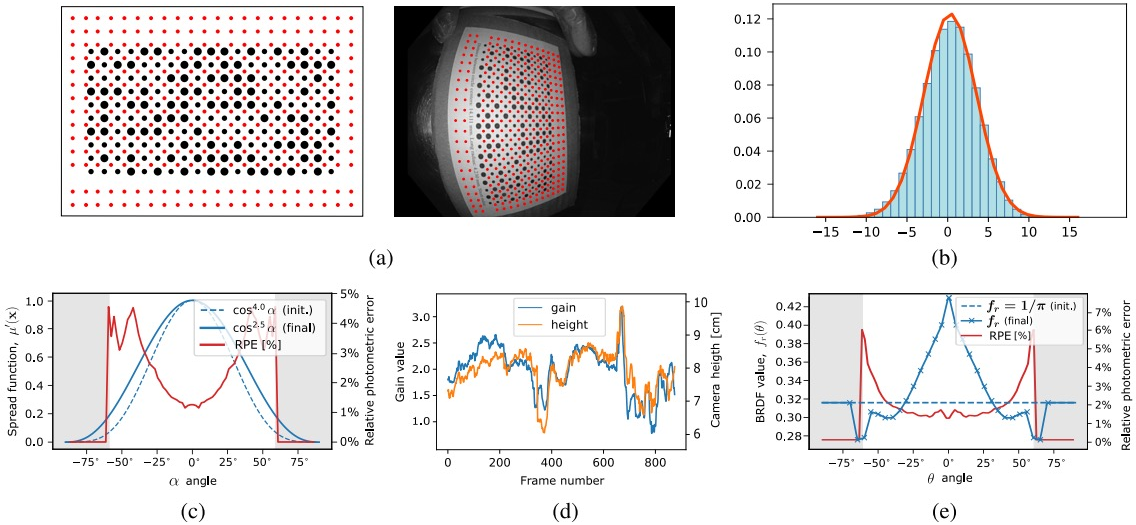
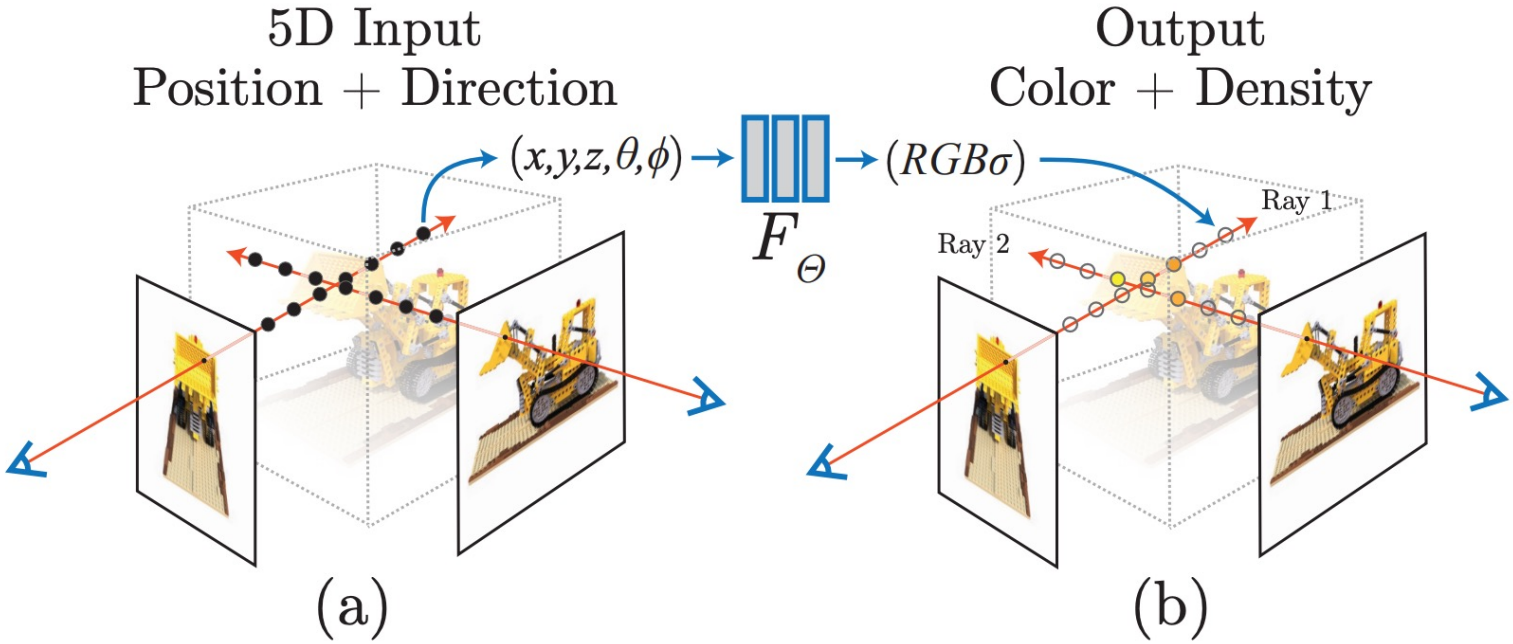


Fig. 3: Sampling the Vicalib pattern: (a) Red marks correspond to each $\boldsymbol{x}_j$ sampled point. Photometric calibration results: (b) Photometric errors of the calibrated model are close to a Gaussian distribution with a mean of 0.3 and std. of 3.2 gray levels. (c) Joint attenuation caused by light spread function $\mu(\mathbf{x})$ and camera vignetting $V(\mathbf{x})$. (d) Estimated auto-gain factors over the calibration video. (e) Non-Lambertian BRDF for the paper sheet used for calibration.

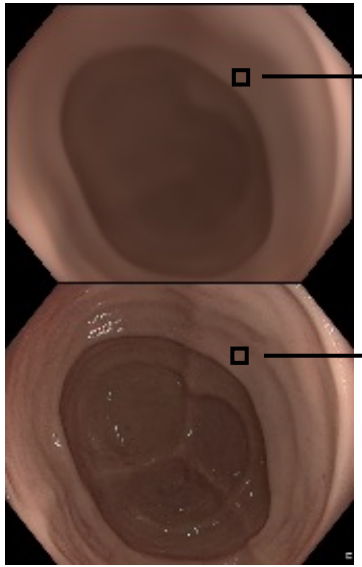
Batlle et al. “Photometric single-view dense 3D reconstruction in endoscopy”. *IROS (2022).*

Radiance Fields

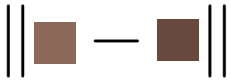


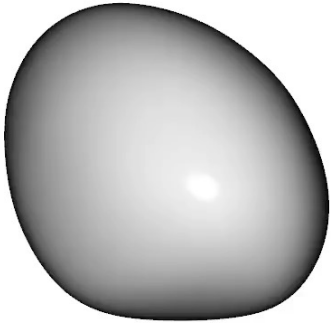
Mildenhall et al. “NeRF: Representing scenes as neural radiance fields for view synthesis.”. *ECCV (2020)*.

Render



$$\mathcal{I}(\mathbf{x}) = \left(\frac{L_e}{t^2} \, \mathrm{BRDF}(\mathbf{x}, \mathbf{d}) \, \cos(\theta) \, g \right)^{1/\gamma}$$

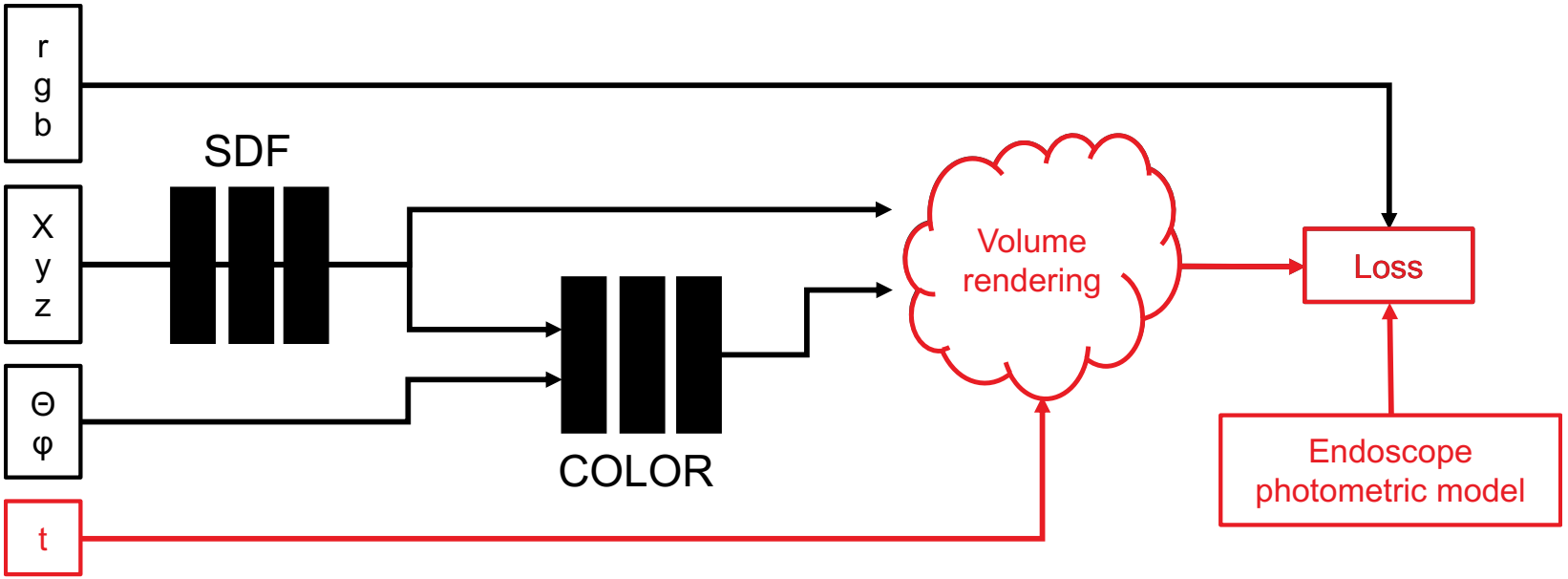




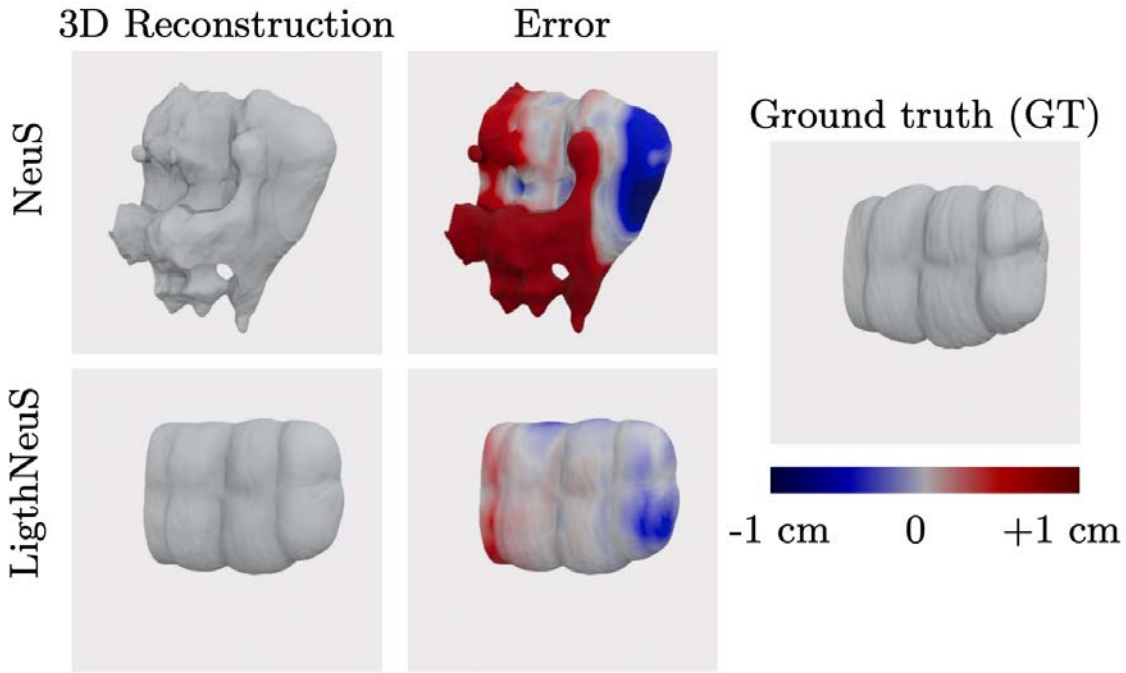
Target

Batlle et al. “LightNeuS: Neural Surface Reconstruction in Endoscopy Using Illumination Decline”. *MICCAI (2023)*.

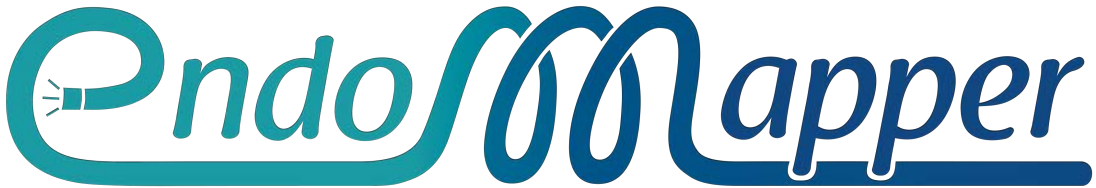
Neural Radiance Fields ▸ NeuS ▸ LightNeus



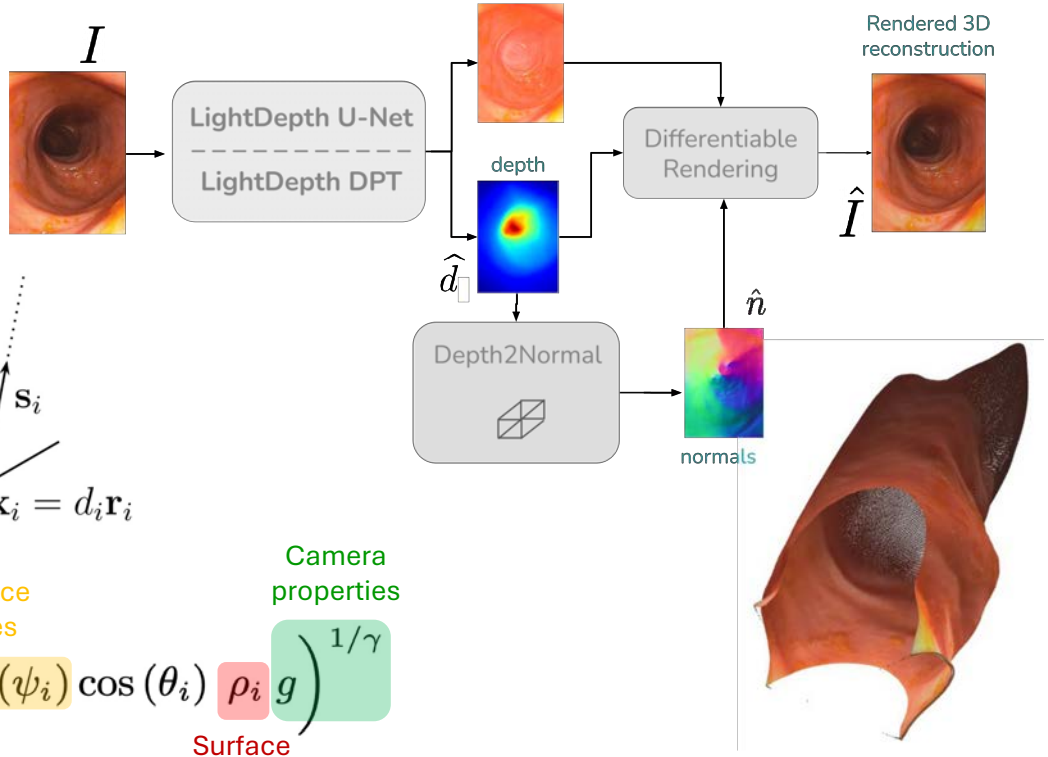
NeuS vs LightNeuS




After inspecting a colon section,


EndoMapper

LightDepth: Single-View Depth Self-Supervision from Illumination Decline



$$\mathcal{I}(d_i, \rho_i, g) = \left(\frac{\sigma_0}{\|d_i\mathbf{r}_i - \mathbf{x}_l\|^2} R(\psi_i) \cos(\theta_i) \rho_i g \right)^{1/\gamma}$$

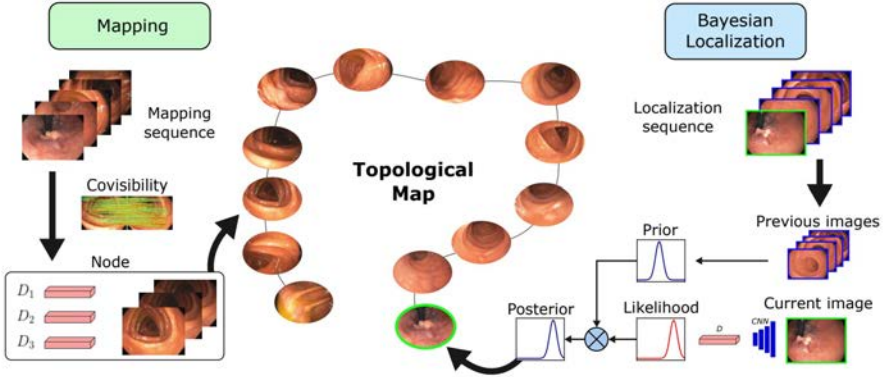
Light source properties

Camera properties

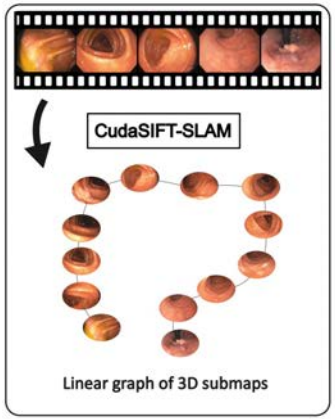
Inverse-square law

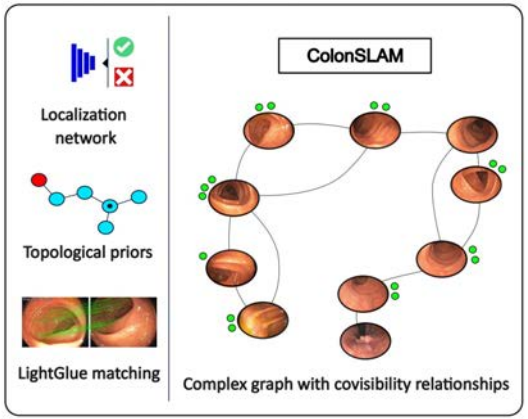
Surface properties

ColonMapper: topological mapping and localization for colonoscopy



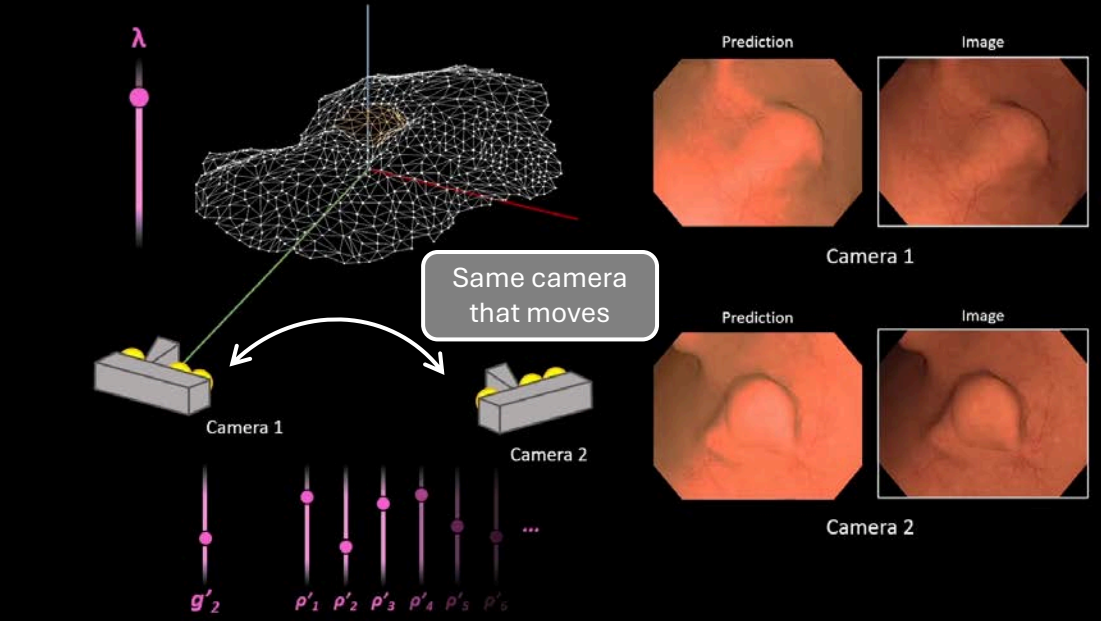
Topological SLAM in colonoscopies leveraging deep features and topological priors





EndoMetric: Near-light metric scale monocular SLAM

Metric scale estimation by minimizing the photometric error



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and more on my website!

SCAN ME