LightDepth

Single-View Depth Self-Supervision from Illumination Decline

J Rodriguez-Puigvert*, VM Batlle*, JMM Montiel, R Martinez-Cantin, P Fua, JD Tardós, J Civera

Take away

- The first **single-view self-supervised method** for depth estimation.
- Light and camera co-located + dark environment (e.g.: **endoscopy**)
- We outperform multi-view self-supervision and **match supervision with ground truth**

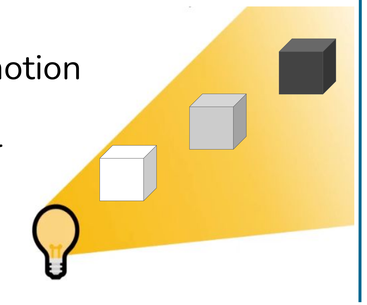
Motivation

Single-View Depth in Endoscopy

- Monocular camera
- Varying illumination
- Untextured surface
- Deformable environment

Illumination decline as single-view self-supervision

- The further, the darker
- No need for depth GT
- No need for camera motion estimation
- Single architecture for training and test-time refinement (TTR)



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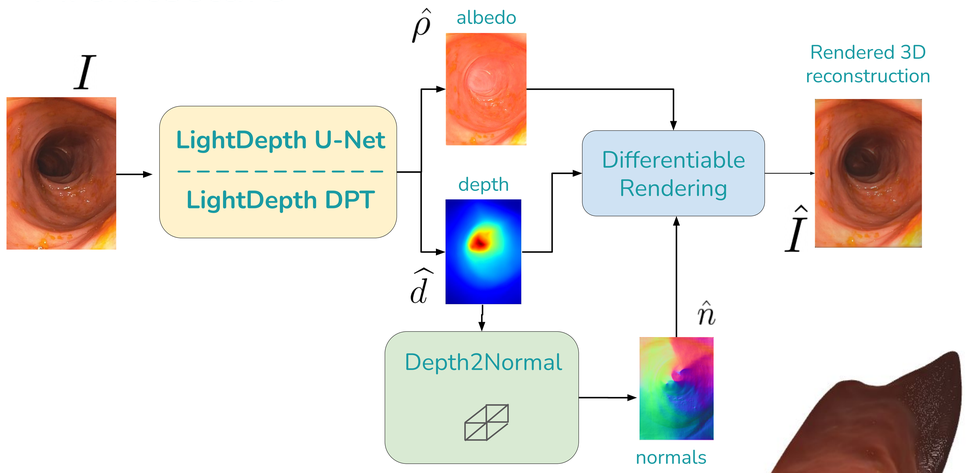
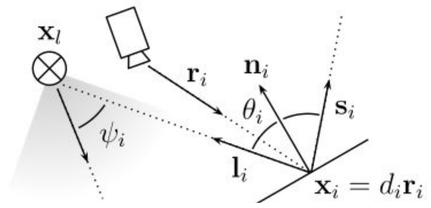
Architecture



Differentiable rendering



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

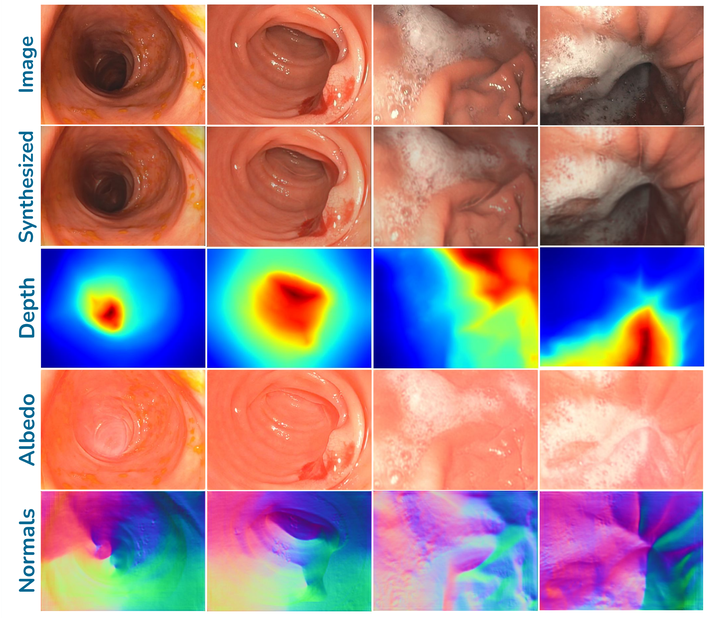
Losses

- Single-view photometric consistency $\mathcal{L}_p = \sum_{i \in \Omega} (I_i - \hat{I}_i)^2$
- Specularity consistency $\mathcal{L}_{sp} = \sum_{i \in \Omega} (\cos \alpha_i - 1)^2$
- Smoothness $\mathcal{L}_s = |\partial_x \hat{d}| e^{-|\partial_x I|} + |\partial_y \hat{d}| e^{-|\partial_y I|}$

Experiments

- Metrics match supervised methods
- Significant better performance than multi-view self-supervision

EndoMapper dataset



Architecture	Backbone	Supervision	MAE ↓	MedAE ↓	RMSE ↓
U-Net	ResNet18	Depth GT	4.15	3.29	5.52
DPT-Hybrid [48]	ResNet50	Depth GT	**3.22**	2.77	**4.10**
Monodepth2 [20]	ResNet50	Multi-View	14.27	9.59	18.64
CADepth [64]	ResNet18	Multi-View	52.35	17.04	87.43
XDCycleGAN [42]	ResNet	Cycle	17.16	11.91	22.43
LightDepth U-Net	ResNet18	Light	4.37	2.92	6.31
LightDepth DPT	ResNet50	Light	3.94	2.67	5.60
LightDepth U-Net	ResNet18	Light (TTR)	3.72	<u>2.59</u>	5.43
LightDepth DPT	ResNet50	Light (TTR)	<u>3.70</u>	**2.58**	<u>5.27</u>