PR-ENDO: Physically Based Relightable Gaussian Splatting for Endoscopy

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Overview

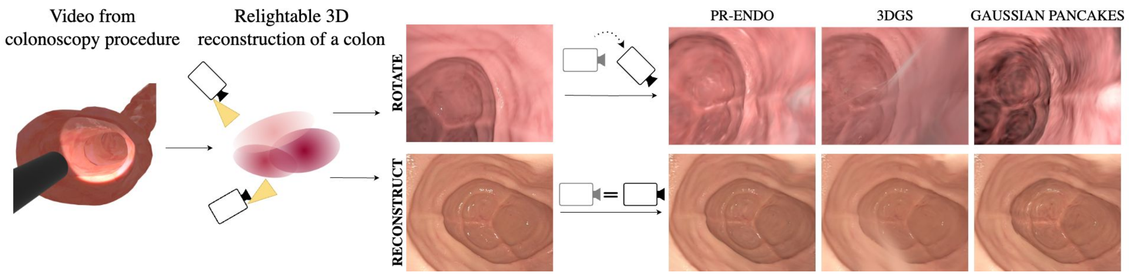

Figure 1. PR-ENDO teaser. PR-ENDO is able to achieve superior reconstruction even with drastical rotation angles.

PR-ENDO is a method based on 3D Gaussian Splatting and PBR (Physically Based Rendering) which gives superior reconstruction results. Thanks to light modelling, it can also update the reconstructed structure based on new lighting conditions or after deformation of the tissue. PR-ENDO can be used to reconstruct and simulate real colon using colonoscopy videos.

Our method

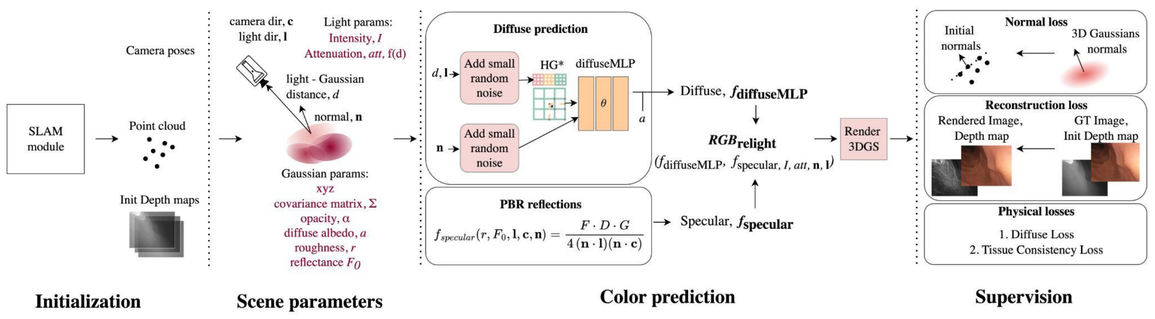

Figure 2. Overview of PR-ENDO pipeline.

PR-ENDO pipeline includes:
(1) Initialization: SLAM module generates camera poses, point cloud and optionally depth maps.
(2) Scene Parameters: Each Gaussian i is defined by position, covariance, opacity, **albedo**, **roughness**, and **reflectivity** (F_0). Light parameters include direction, intensity and attenuation function.
(3) Prediction: **diffuseMLP** predicts the diffuse component, while the **PBR model** calculates specular reflection. The final color $RGB_{relighted}$ **combines diffuse and specular terms**.
(4) Supervision: Normal, reconstruction and physical losses are applied during training.

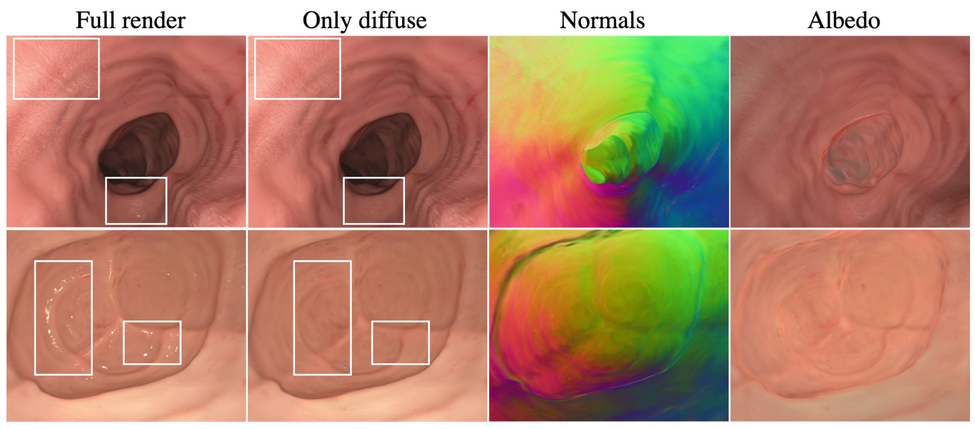

Figure 3. Decomposition. Our physically motivated model decomposes the render into specular, diffuse and albedo views. It can also model plausible normals.

Results

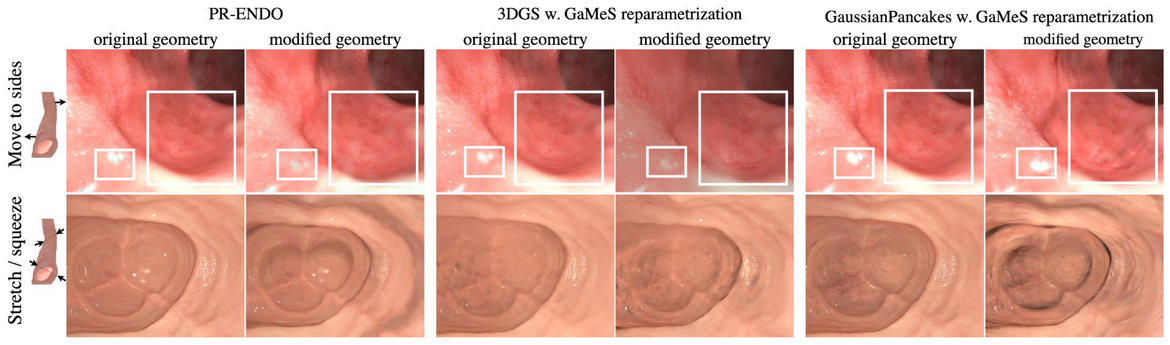

Figure 4. Anatomy modification using Blender and cage-based simulations. PR-ENDO ensures accurate tissue responses to light and corrects it after deformation, unlike 3DGS or GaussianPancakes.

Model	C3VD			RotateColon		
	PSNR ↑	SSIM ↑	LPIPS ↓	PSNR ↑	SSIM ↑	LPIPS ↓
3DGS [13]	33.90	0.89	0.28	20.29	0.82	**0.25**
EndoGSLAM [27]	22.16	0.77	**0.22**	-	-	-
GaussianPancakes [3]	33.12	0.89	0.30	20.10	0.88	0.27
GaussianShader [11] *	29.82	0.86	0.40	21.25	0.87	0.38
3DGS-DR [14]	33.77	0.89	0.31	21.49	**0.89**	0.28
PR-ENDO (ours)	**34.24**	**0.90**	0.29	**21.90**	0.88	0.27

Table 1. Performance comparison on C3VD and RotateColon datasets.
*While GaussianShader performs well in terms of metrics, it fails to accurately reconstruct scene geometry.

We performed quantitative comparison with previous methods on C3VD and RotateColon dataset (Tab. 1). C3VD (Colonoscopy 3D Video Dataset) is existing dataset while RotateColon is a simple dataset created by us which consisted of drastic rotation angles in the test data.
Additionally, we performed cage-based simulations using Blender and GaMeS representation using PR-ENDO, 3DGS and GaussianPancakes (Fig. 3).

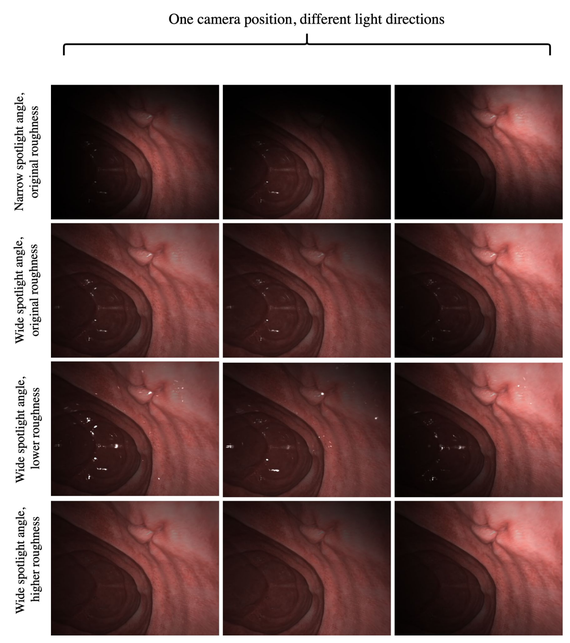

Figure 5. Qualitative evaluation of light and tissue properties separation. PR-ENDO enables effective novel camera positioning, light parameters adjustments.

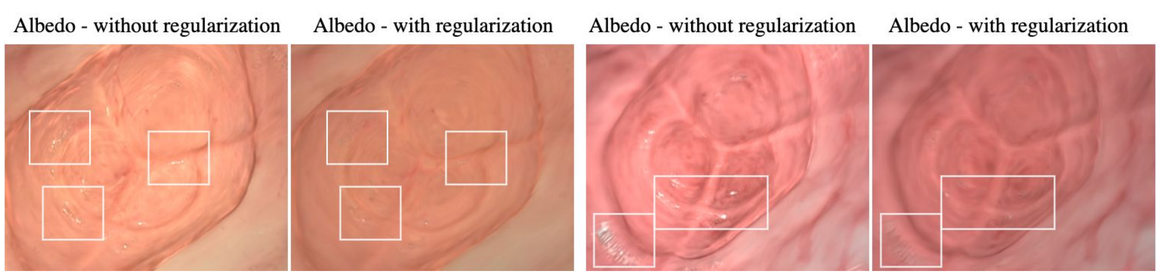

Figure 6. Ablation study of our albedo regularization.

Conclusions

PR-ENDO is able to reconstruct the colon tissue based on colonoscopy procedure. Not only that but it also models probable roughness and reflectivity which enables easy modification. PR-ENDO could be used in physical simulations of the colon or AR/VR to create realistic training materials for new doctors.

checkout our project website to see our cool videos & paper!