HFGS: 4D Gaussian Splatting with Emphasis on Spatial and Temporal High-Frequency Components for Endoscopic Scene Reconstruction

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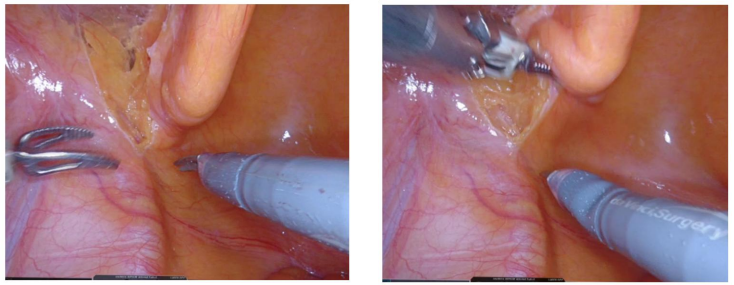
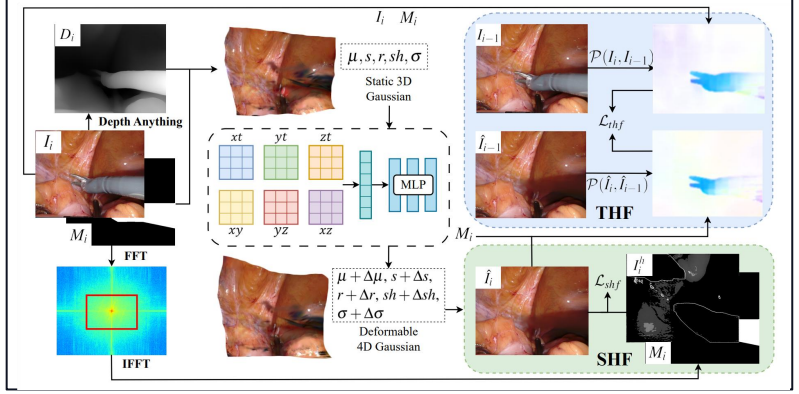
Task

In Robotic-Assisted Minimally Invasive Surgery (RAMIS), the reconstruction of a 3D model of the surgical scene is critical!

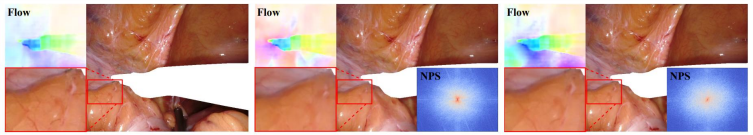


HFGS not only achieves **the best results**, and exhibiting **the bluest NPS**, but also renders images with optical flow that are **closer** to the GT.



Method

In this paper,
1) We propose a Frequency Regularization Module to **reduce spectral mismatches**.
2) We introduce a module which offers dynamic awareness with the help of **flow prior**.
3) HFGS achieves superior performances.



(a) GT (b) EndoGS [42] (c) HFGS

Results

Method	ENDONERF PSNR↑	ENDONERF SSIM↑	ENDONERF LPIPS↓	SCARED PSNR↑	SCARED SSIM↑	SCARED LPIPS↓	FPS
EndoNeRF [28]	34.20	0.935	0.156	23.52	0.754	0.400	0.2
ForPlane-9k [31]	33.63	0.918	0.100	22.68	0.745	0.431	1.7
ForPlane-32k [31]	36.65	0.947	0.056	23.50	0.762	0.348	1.7
EndoSurf [39]	34.99	0.955	0.113	23.94	0.779	0.384	0.04
EndoGS [42]	36.84	0.963	0.041	26.46	0.770	0.339	~70
EndoGaussian [43]	37.99	0.966	0.043	26.39	0.792	0.530	~100
HFGS	38.14	0.971	0.033	27.47	0.796	0.311	~70

Table 1: Quantitative metrics of appearance (PSNR/SSIM/LPIPS) on ENDONERF [28] and SCARED [1]. The best and the second best results are denoted by pink and yellow.

Method	ENDONERF-pulling PSNR	SSIM	LPIPS	ENDONERF-cutting PSNR	SSIM	LPIPS
Baseline	36.27	0.933	0.057	37.00	0.961	0.036
Ours w/o SHF	38.06	0.967	0.044	37.51	0.969	0.024
Ours w/o THF	37.93	0.965	0.044	37.67	0.968	0.023
Ours	38.44	0.968	0.043	37.83	0.969	0.022

Table 2: Ablation studies on the impact of each module in our method on ENDONERF [28].

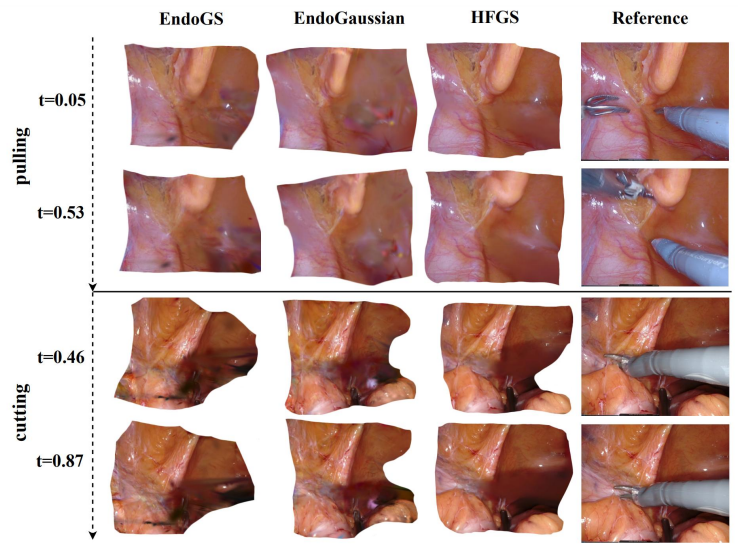


Figure 3: Illustration of reconstruction results of previous works and ours on scene "pulling soft tissues" and "cutting tissues twice" on ENDONERF [28].

Conclusion

A method for deformable endoscopic tissue reconstruction that leverages **spatial and temporal frequency** analyses.
Future work should focus on integrating **multiple surgical cameras** to enhance 3D tissue reconstruction accuracy and practicality in clinical environments.

Code at https://github.com/zhaohaoyu376/HFGS