

DDGS-CT

Direction-Disentangled Gaussian Splatting for Realistic Volume Rendering



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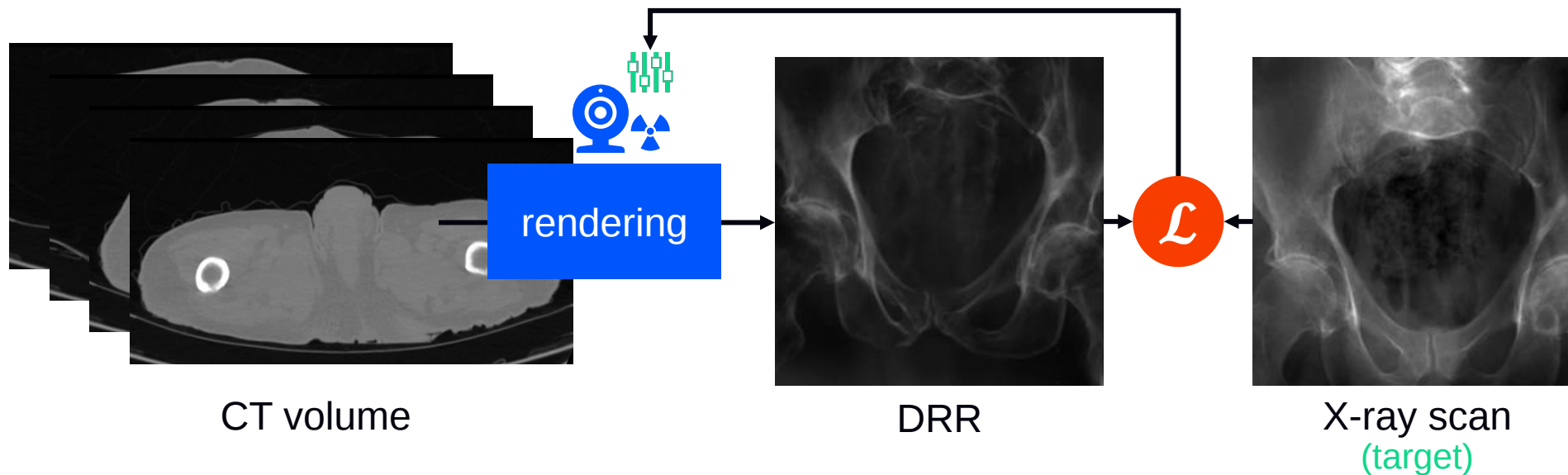
Ziyang Wu



video contains voice-over explanations

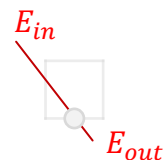
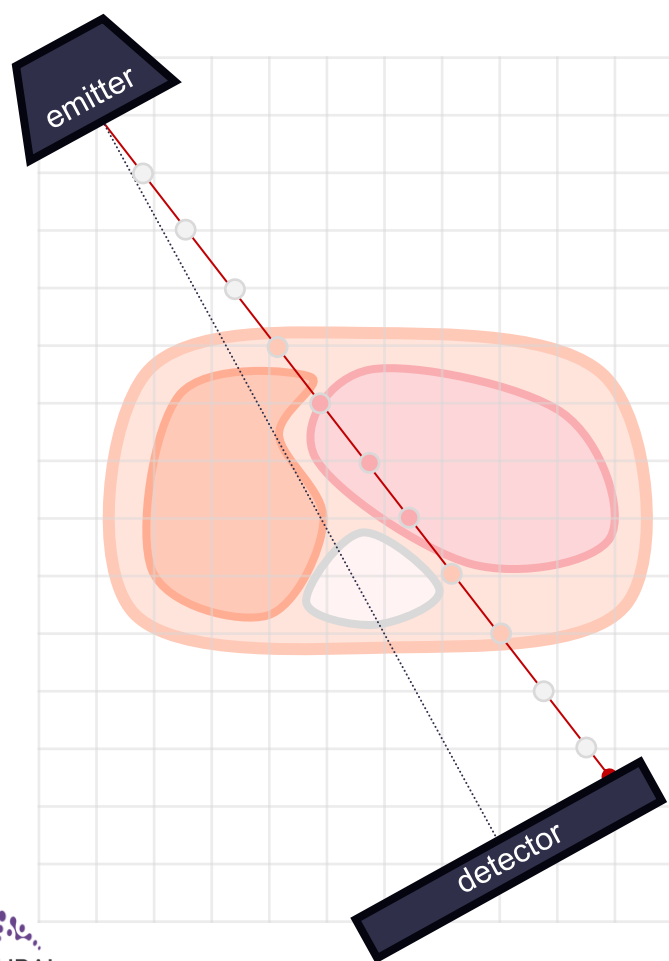


- **Definition:** simulated projections of 3D CT volumes, generated through ray-tracing.
- **Application:** visualization, pose registration of real X-ray images.
- **Limitations:** slow rendering, simplistic isotropic modeling of photon/matter interactions.



Primary imaging contribution

= averaged attenuation of photon energy through the volume.



E_{in} = photon energy, avg. over n samples

energy attenuation

$$E_{out} = E_{in} - \Delta E$$

$$= E_{in} - \underbrace{\Delta E_{pe}}_{\substack{\checkmark \text{ photoelectric effect} \\ \text{function of } E_{in} \text{ \& material}}} - \underbrace{\Delta E_{cs}}_{\substack{\text{compton scattering} \\ \text{function of } E_{in} \text{ \& material}}} - \Delta E_{rs}$$

✓ rayleigh scattering
can be ignored, low probability

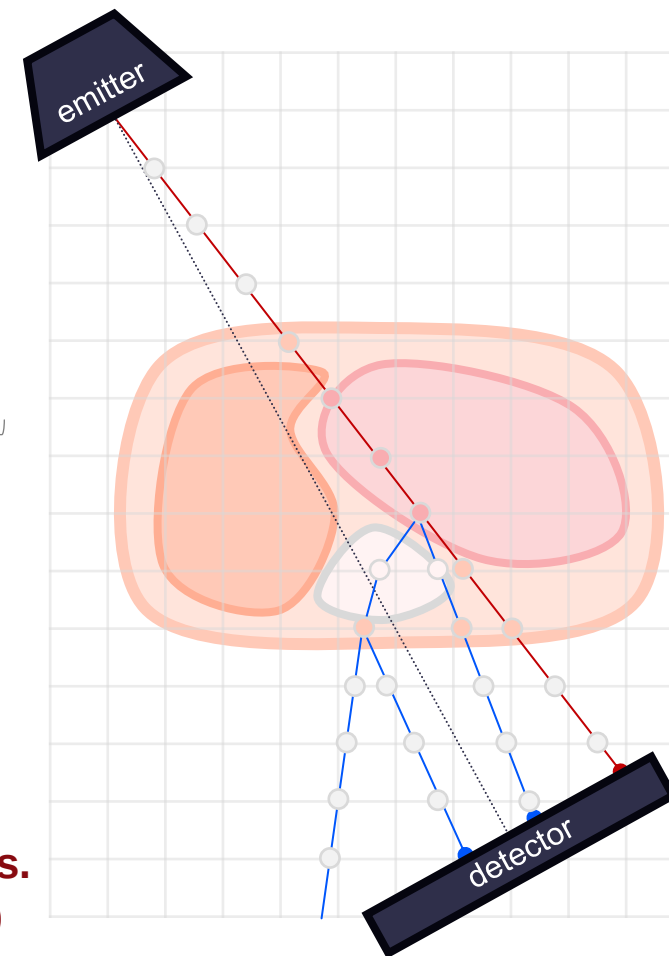
assumption: photon attenuation is isotropic.

... but is it correct?

→ **Prior work ignore anisotropic contributions.**
(too heavy to compute, require material information)

Anisotropic contributions

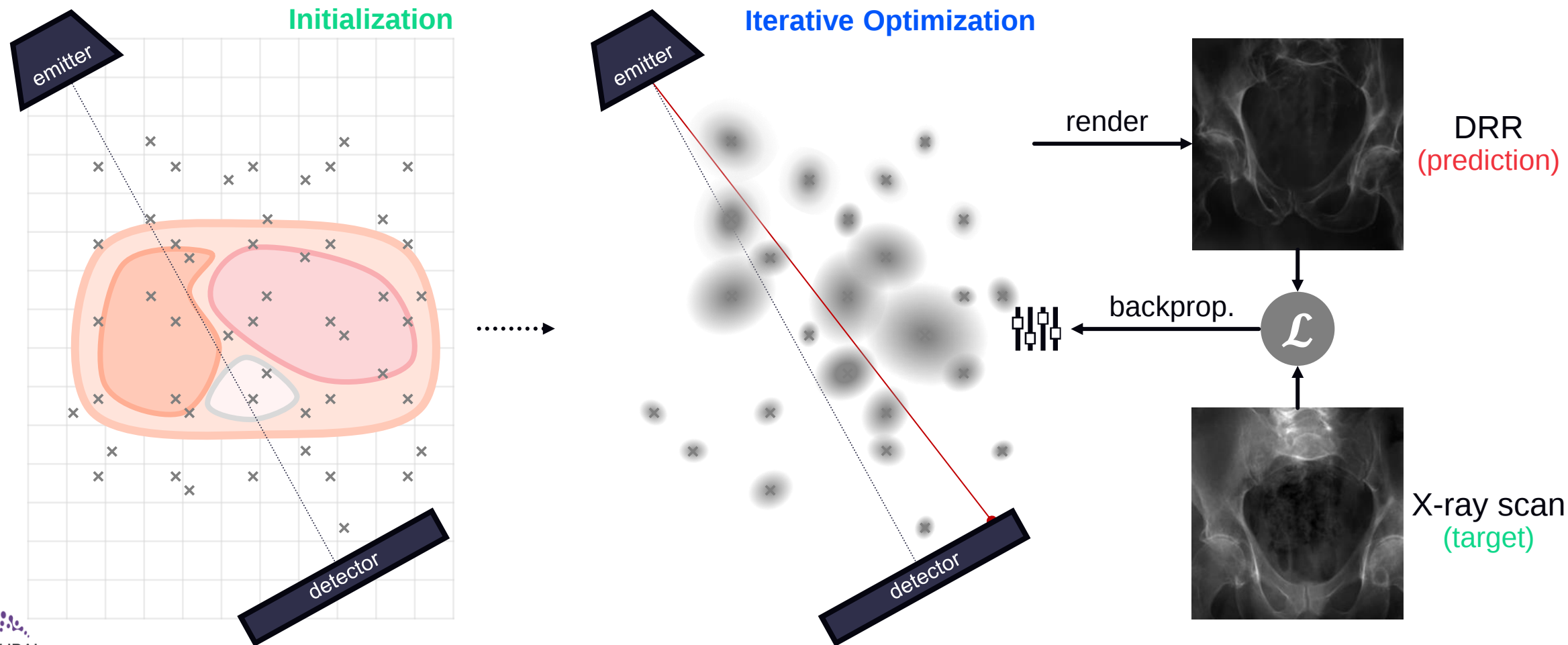
= noise from secondary rays (scattered photons).



✓

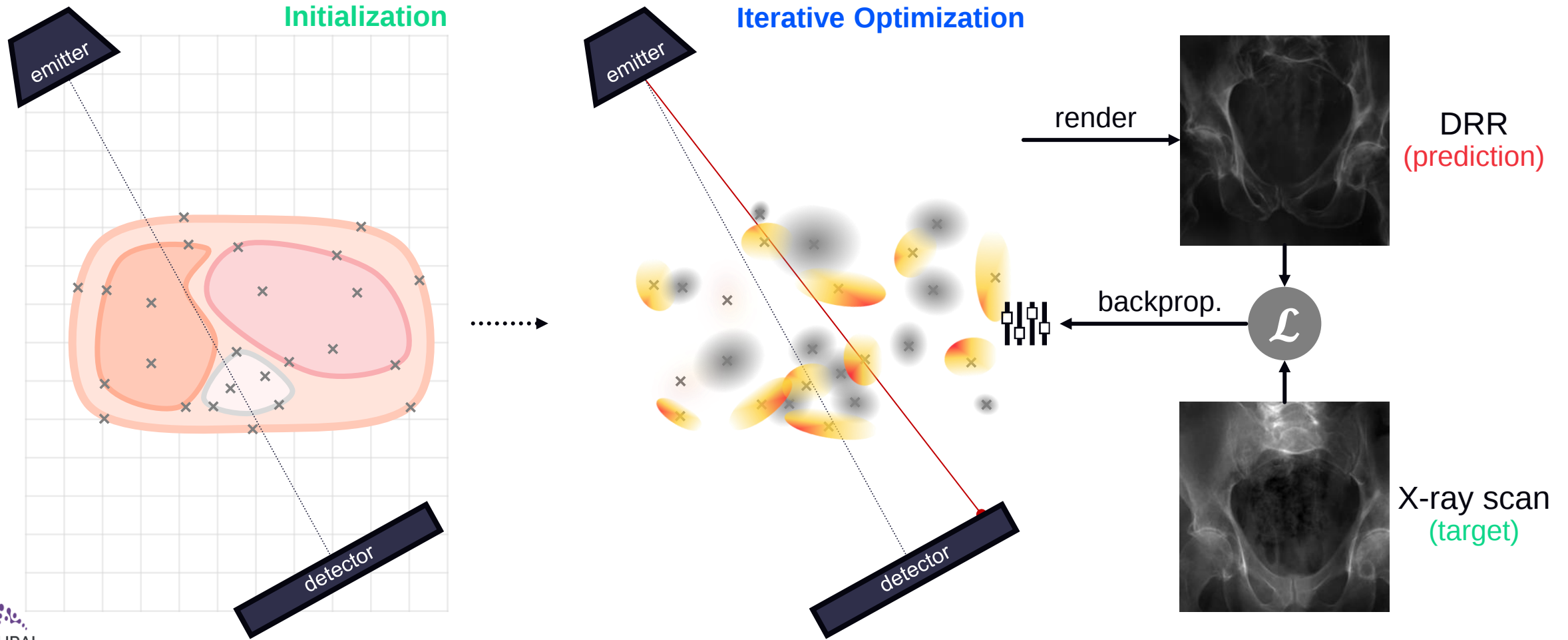
X-Gaussian, GaSpCT, etc. = vanilla Gaussian splatting applied to DRR

= initialization ignoring CT information, naïve isotropic Gaussians



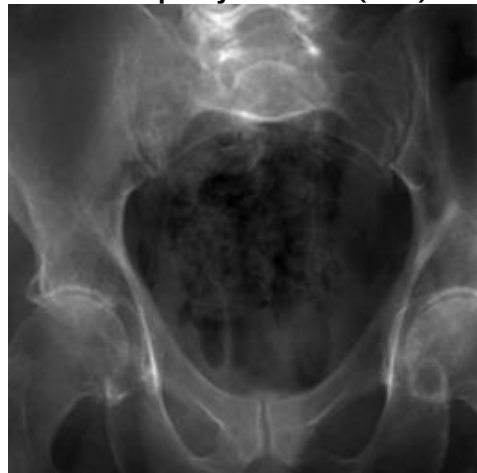
1. Cai, Yuanhao, et al. "Radiative gaussian splatting for efficient x-ray novel view synthesis." *ECCV 2024*.
2. Nikolakis, Emmanouil, et al. "GaSpCT: Gaussian Splatting for Novel CT Projection View Synthesis." *arXiv 2024*.

- **Initializing via Radiodensity-Aware Dual Sampling** – 3D points are sampled from organ surfaces and via intensity-based sampling.
- **Disentangling Isotropic and Anisotropic 3D Gaussians** – photon scattering is approximated via a 2nd set of anisotropic Gaussians.



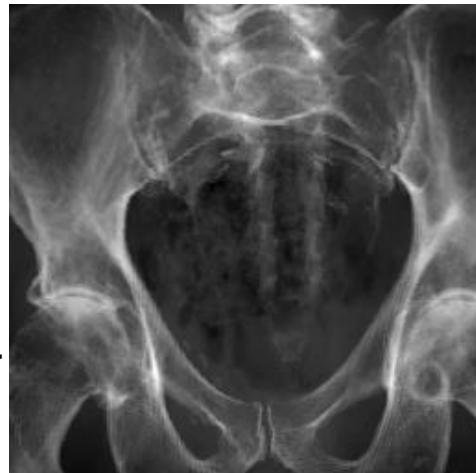
dataset: DeepFluoro

real projection (GT)

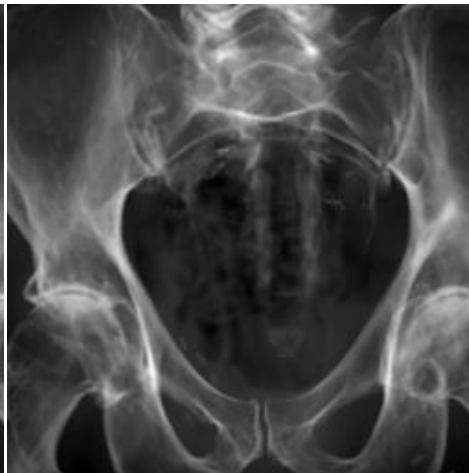


predictions

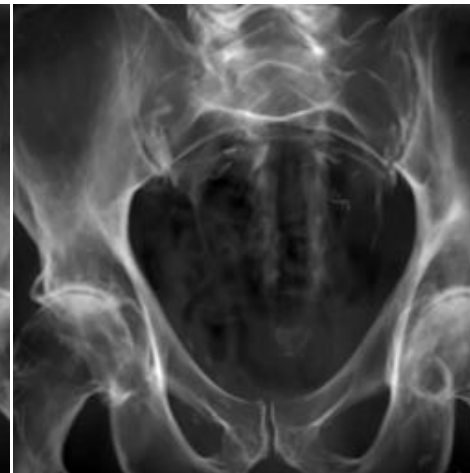
DiffDRR



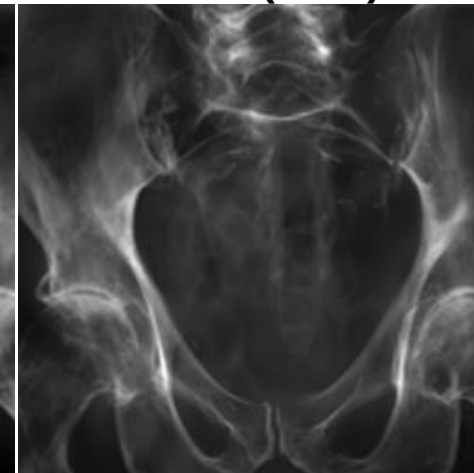
3DGS



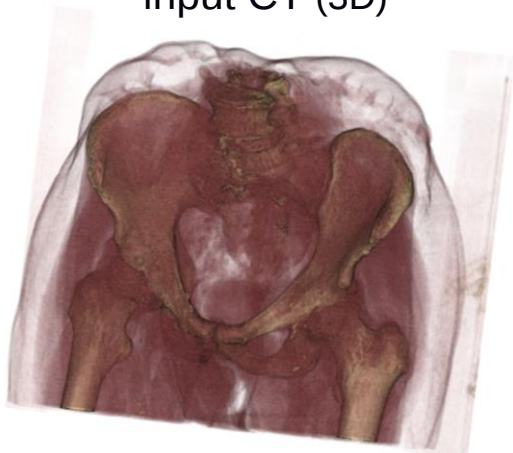
X-Gaussian



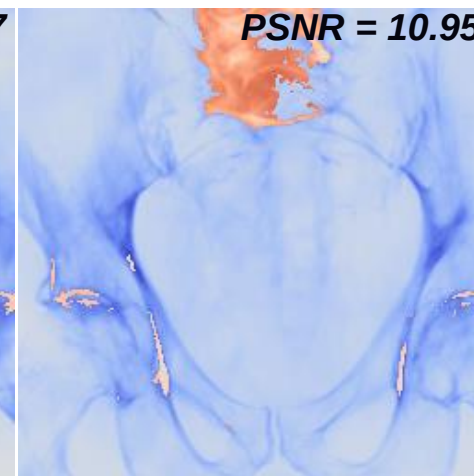
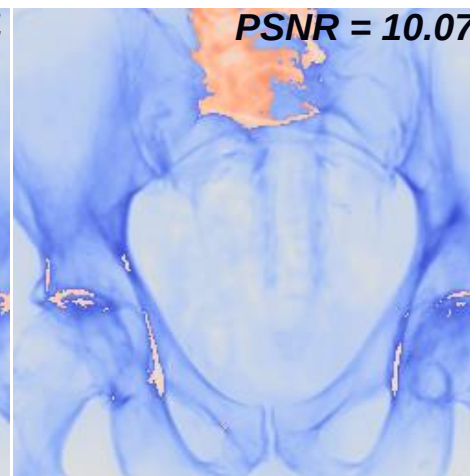
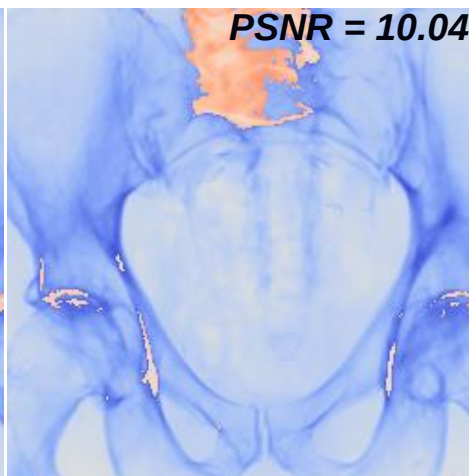
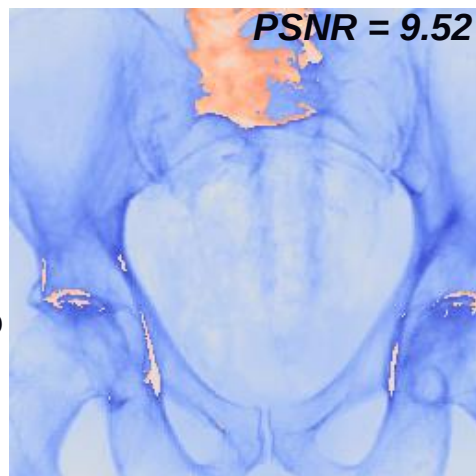
DDGS (ours)

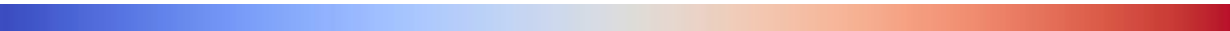


input CT (3D)



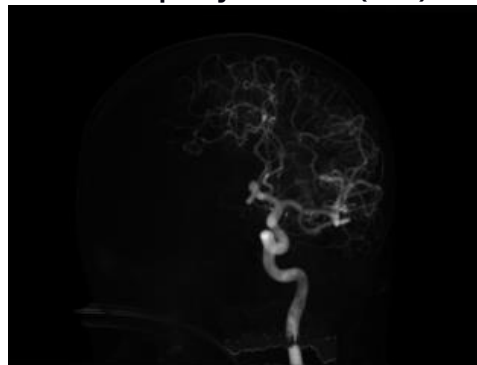
signed error



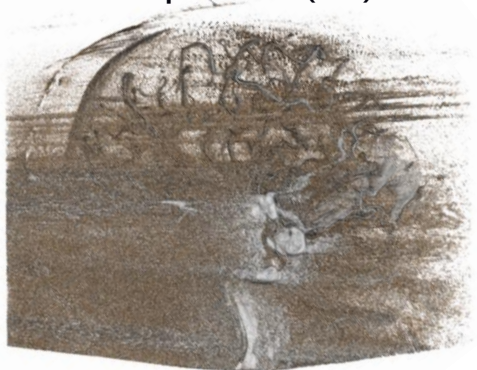
error legend: -1  +1

dataset: Ljubljana

real projection (GT)



input CT (3D)



predictions

DiffDRR



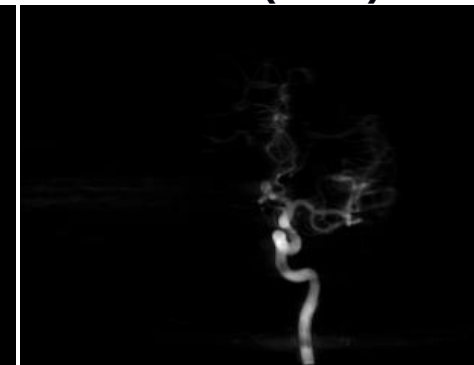
3DGS



X-Gaussian

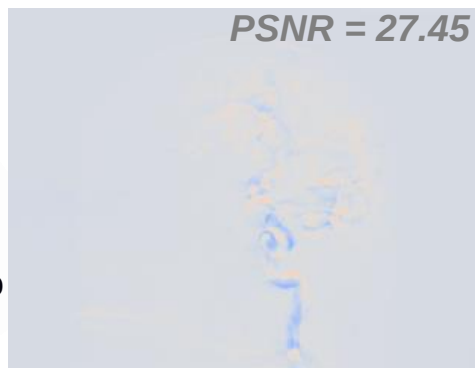


DDGS (ours)

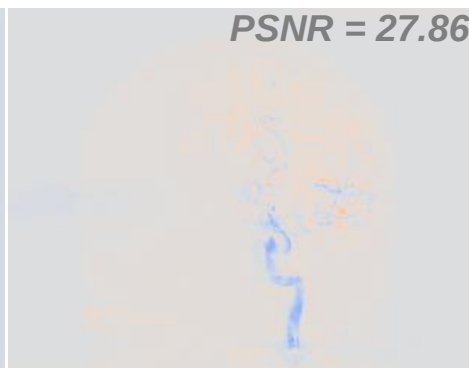


signed error

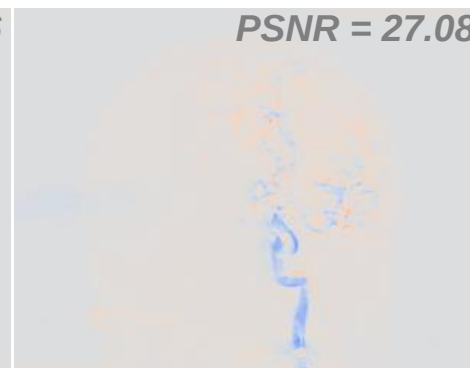
PSNR = 27.45



PSNR = 27.86

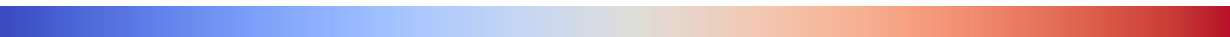


PSNR = 27.08



PSNR = 28.48

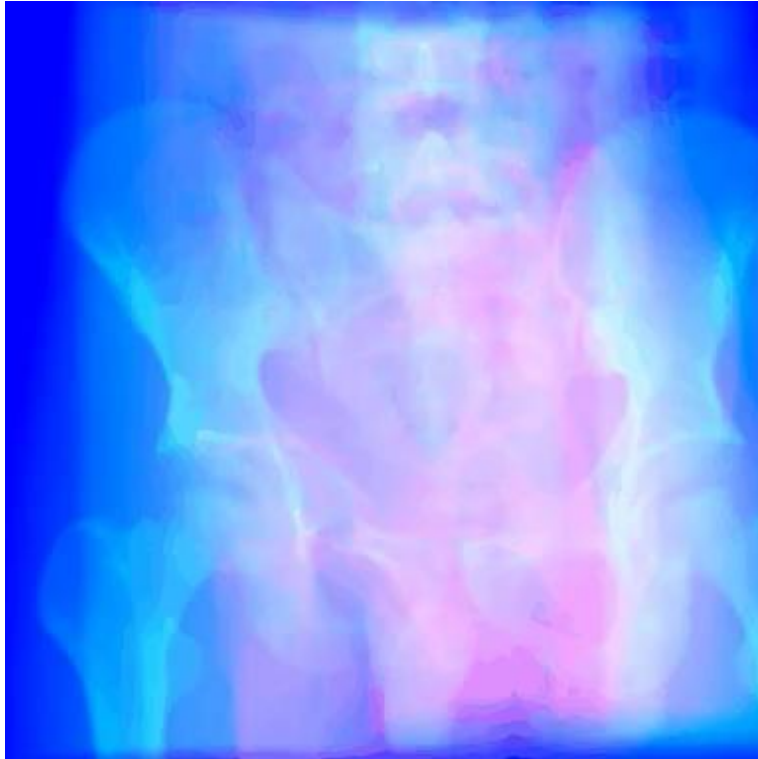


error legend: -1  +1

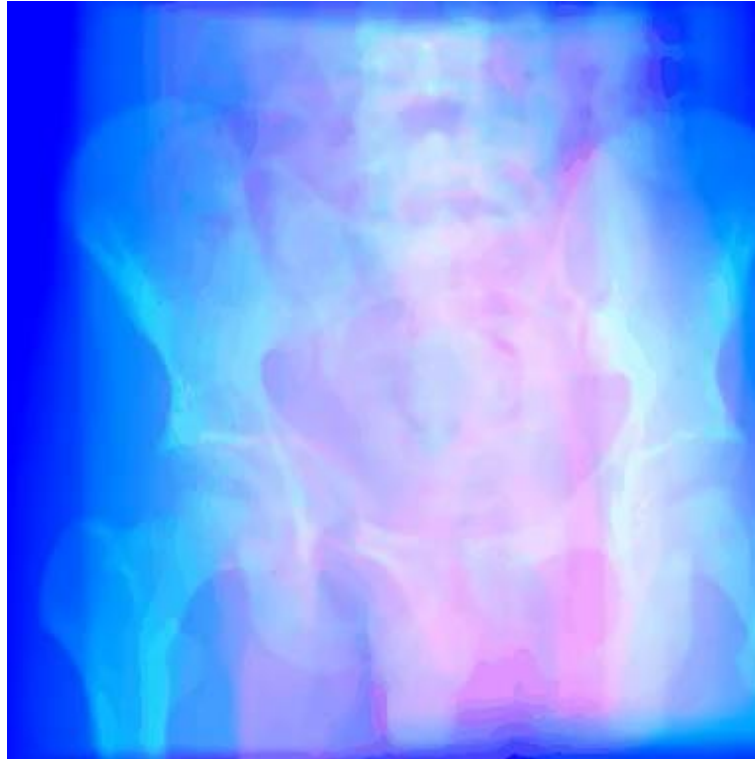
		3DGS			X-Gaussian			DDGS (ours)		
		# points ↓	PSNR ↑	SSIM ↑	# points ↓	PSNR ↑	SSIM ↑	# points ↓	PSNR ↑	SSIM ↑
NAF-CT	abdomen	11,149	47.430	0.994	10,802	47.170	0.993	13,928	48.090	0.994
	chest	13,669	44.420	0.988	16,568	43.330	0.987	13,533	44.500	0.989
	foot	8,616	44.510	0.984	10,909	44.340	0.985	10,786	44.700	0.985
	jaw	17,902	40.470	0.973	22,318	40.020	0.972	19,665	40.570	0.974
	avg	12,834	44.210	0.985	15,149	43.720	0.984	14,478	44.470	0.986
CTPe1vic1K #6	1	53,988	35.400	0.971	50,059	36.810	0.979	41,947	37.880	0.984
	2	49,099	37.030	0.982	48,113	37.790	0.986	43,933	38.430	0.988
	3	60,755	35.730	0.973	59,822	36.460	0.977	48,536	38.280	0.983
	4	42,349	38.870	0.982	37,243	39.840	0.985	39,176	40.350	0.986
	5	42,482	39.370	0.984	46,014	39.300	0.984	39,570	40.360	0.987
	6	53,832	37.140	0.983	57,197	37.420	0.983	47,398	38.260	0.986
	7	45,360	37.090	0.980	48,454	37.620	0.983	41,032	38.870	0.987
	8	51,211	38.030	0.980	45,750	38.700	0.982	43,577	39.810	0.986
	9	44,060	38.190	0.981	41,279	38.920	0.985	41,389	39.870	0.987
	10	38,691	37.800	0.984	40,030	37.550	0.985	39,691	38.730	0.987
	avg	48,183	37.470	0.980	47,396	38.040	0.983	42,625	39.080	0.986

dataset: CTPelvic1K

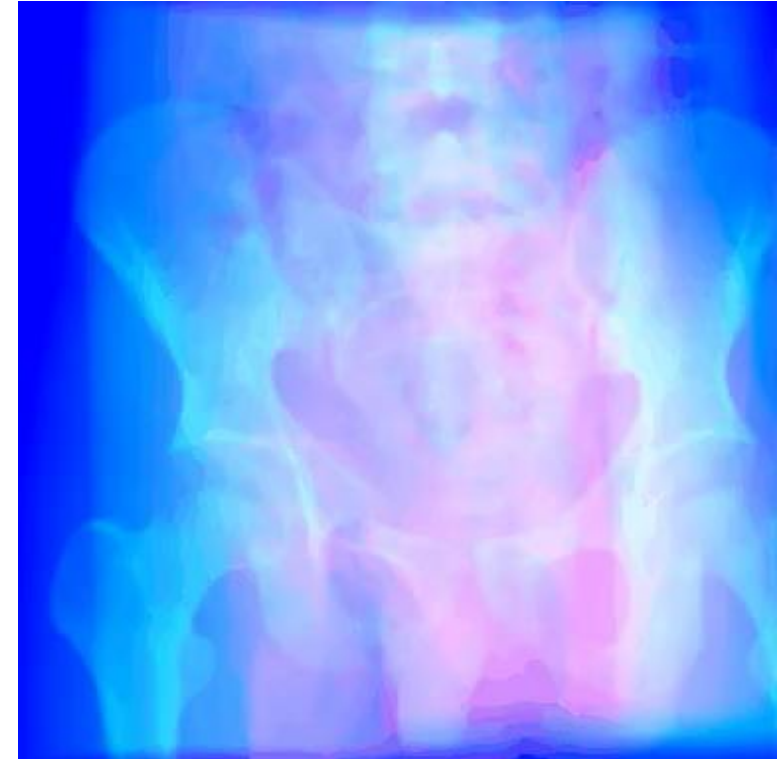
3DGS



X-Gaussian



DDGS (ours)



red channel = target real X-ray scan



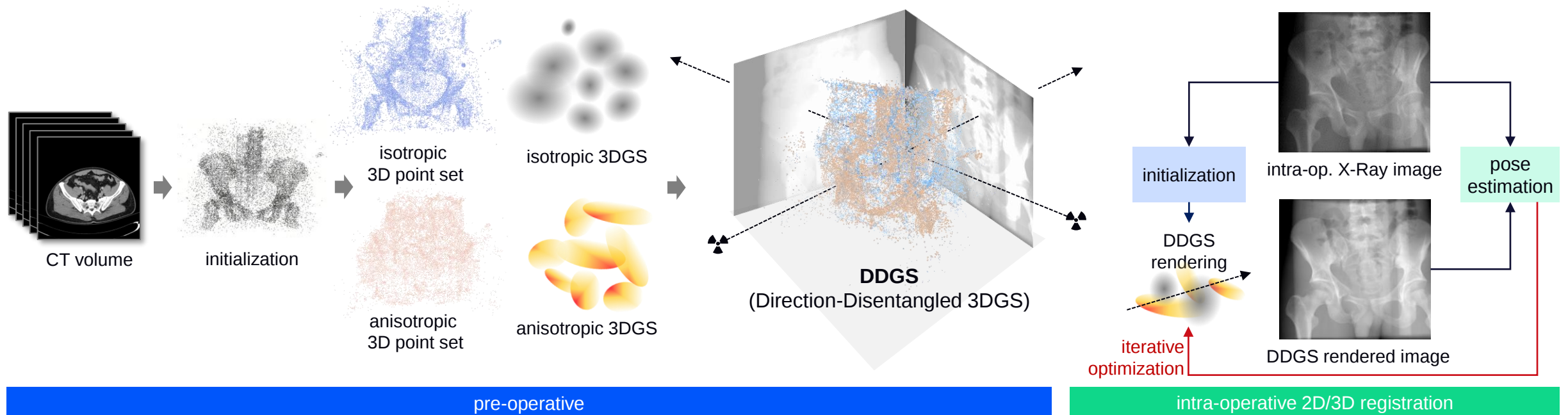
blue channel = predicted DRR

Contributions:

- **Initializing via Radiodensity-Aware Dual Sampling** – 3D points are sampled from organ surfaces and via intensity-based sampling.
- **Disentangling Isotropic and Anisotropic 3D Gaussians** – photon scattering is approximated via a 2nd set of anisotropic Gaussians.

Applications:

- **Realistic DRR Visualization** – DDGS can better approximate anisotropic phenomena impacting X-ray imaging.
- **Intraoperative 2D/3D Registration** – DDGS improves the speed and accuracy of optimization-based pose estimation.



Thank you for your attention! ✓

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