DDGS-CT

Direction-Disentangled Gaussian Splatting for Realistic Volume Rendering


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video contains voice-over explanations

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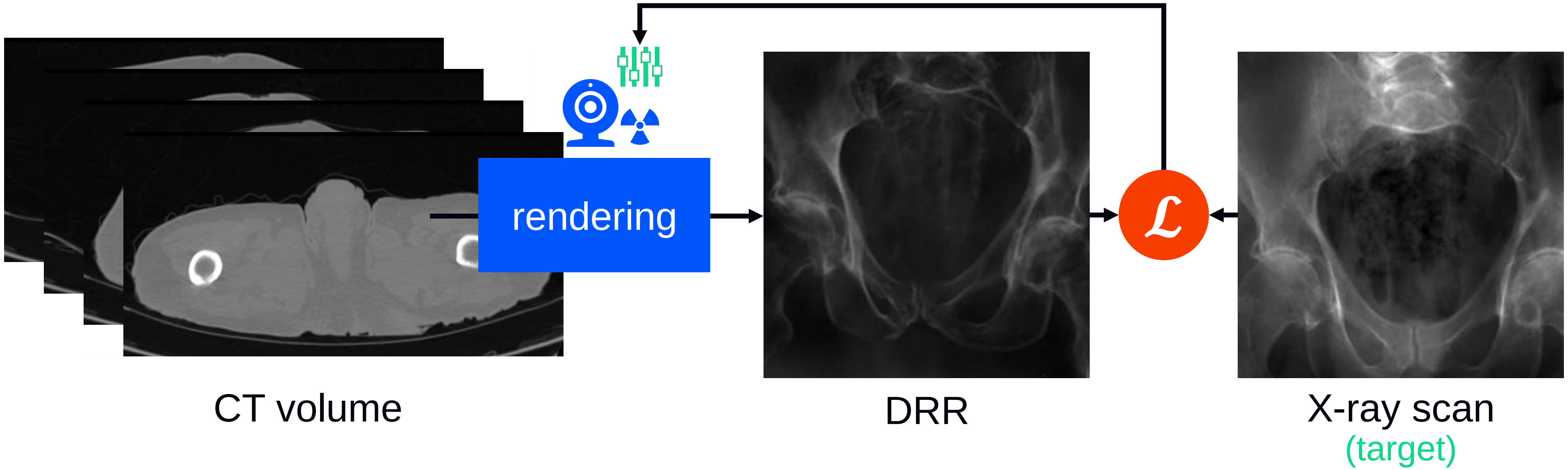
- **Definition**: simulated projections of 3D CT volumes, generated through ray-tracing.
- **Application**: visualization, pose registration of real X-ray images.
- **Limitations:** slow rendering, simplistic isotropic modeling of photon/matter interactions.



DDGS-CT / motivation / isotropic attenuation vs. anisotropic scattering

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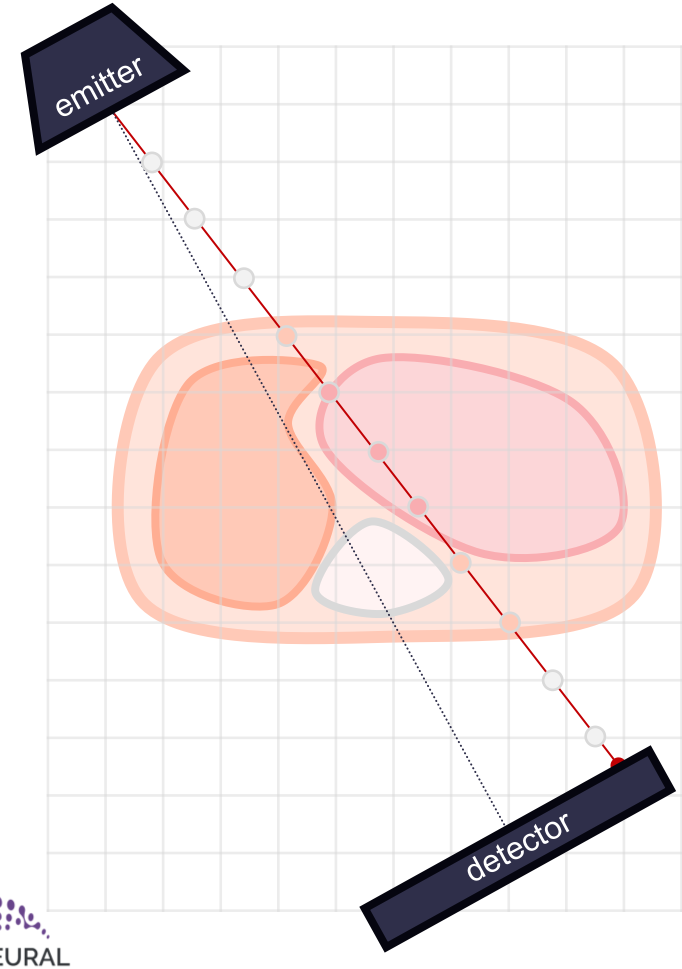
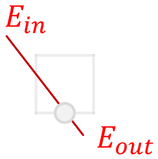
Primary imaging contribution

= averaged attenuation of photon energy through the volume.





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

$$E_{out} = \underbrace{E_{in} - \Delta E}_{\text{energy attenuation}}$$

$$= E_{in} - \Delta E_{pe} - \Delta E_{cs} - \Delta E_{rs}$$

- ✓ photoelectric effect (ΔE_{pe}): function of E_{in} & material
- ✗ compton scattering (ΔE_{cs}): function of E_{in} & material
- ✓ rayleigh scattering (ΔE_{rs}): can be ignored, low probability

assumption: photon attenuation is isotropic.

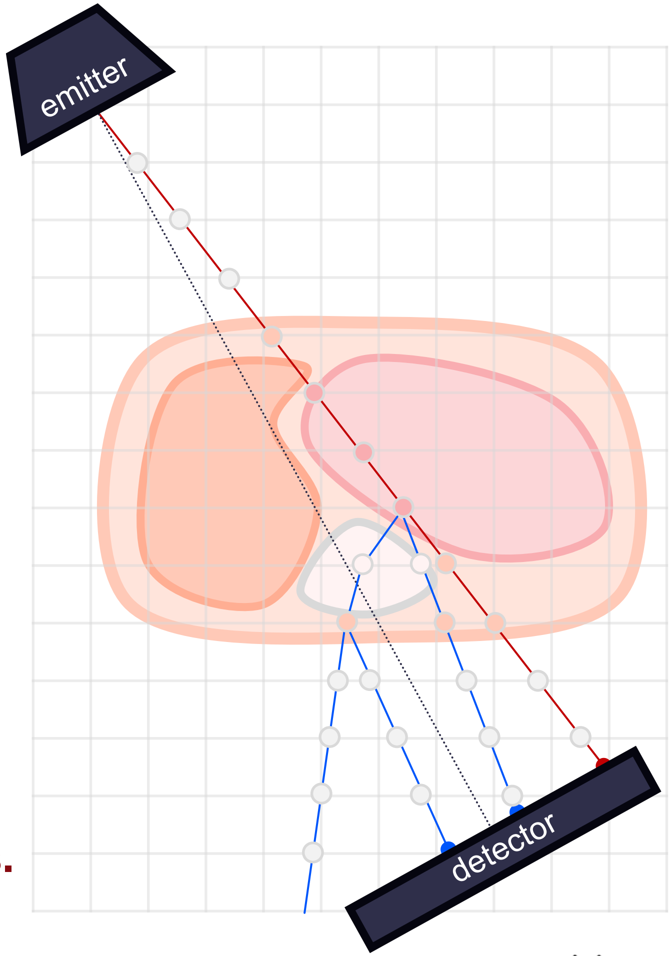
… but is it correct?

→ **Prior work ignore anisotropic contributions.**

(too heavy to compute, require material information)

Anisotropic contributions

= noise from secondary rays (scattered photons).



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DDGS-CT / prior work / Gaussian splatting for DRR rendering

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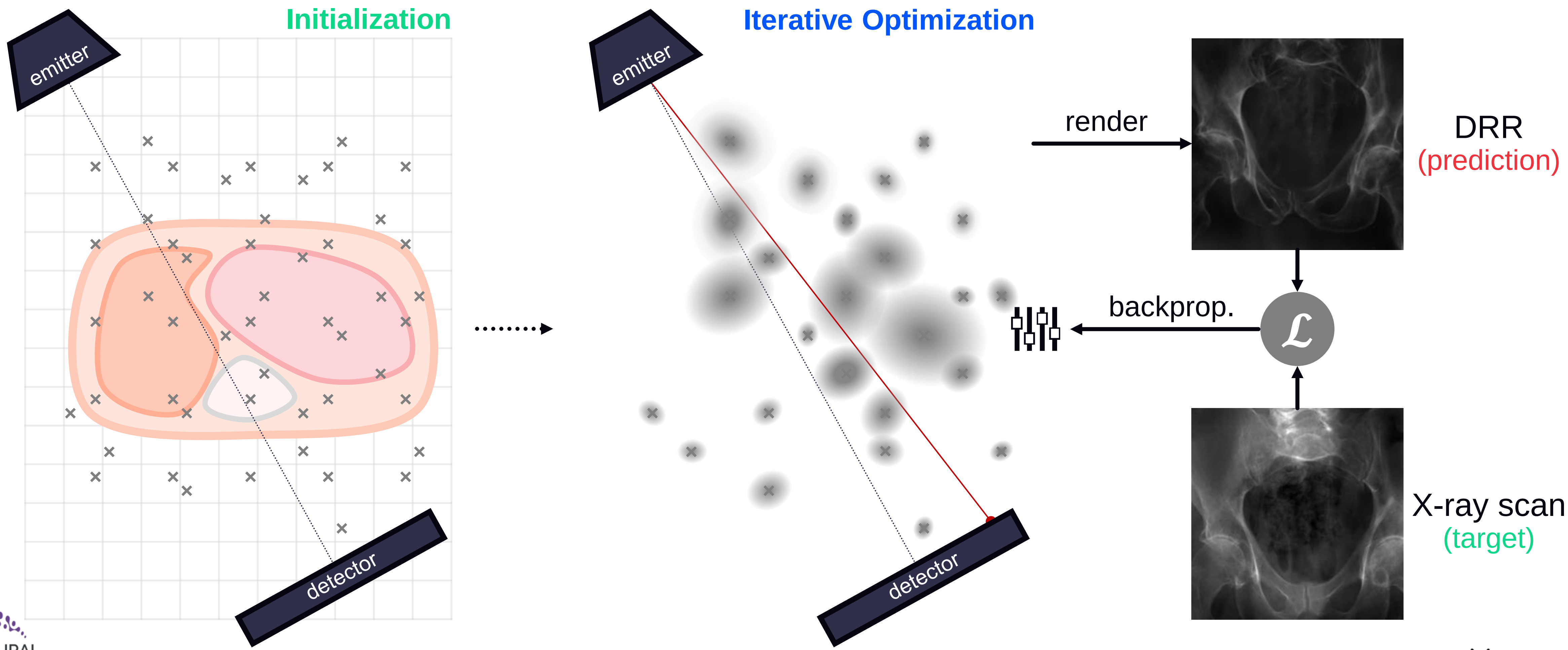
X-Gaussian, GaSpCT, etc. = vanilla Gaussian splatting applied to DRR
= initialization ignoring CT information, naïve isotropic Gaussians



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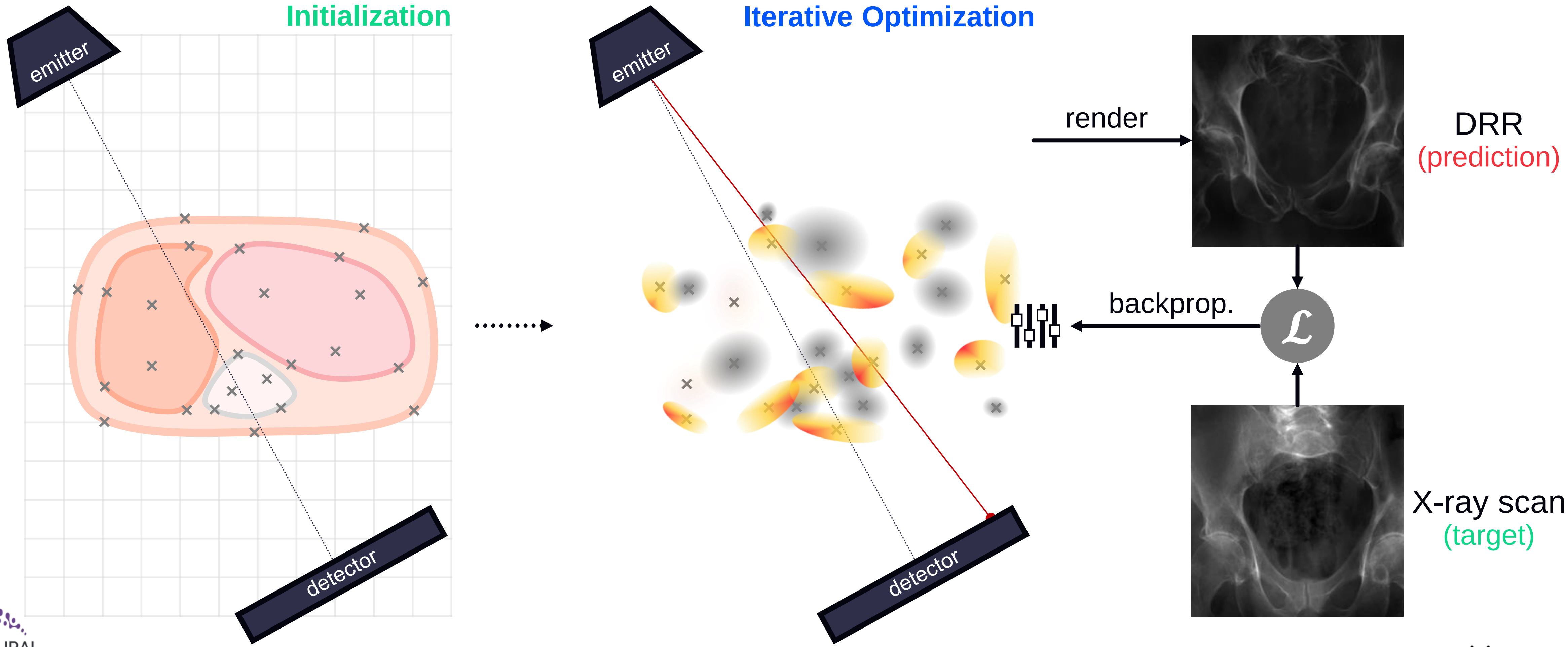
1. Cai, Yuanhao, et al. "Radiative gaussian splatting for efficient x-ray novel view synthesis." *ECCV 2024*.
2. Nikolakakis, Emmanouil, et al. "GaSpCT: Gaussian Splatting for Novel CT Projection View Synthesis." *arXiv 2024*.

Physics-inspired 3DGS for DRR

- **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 2^{nd} set of anisotropic Gaussians.



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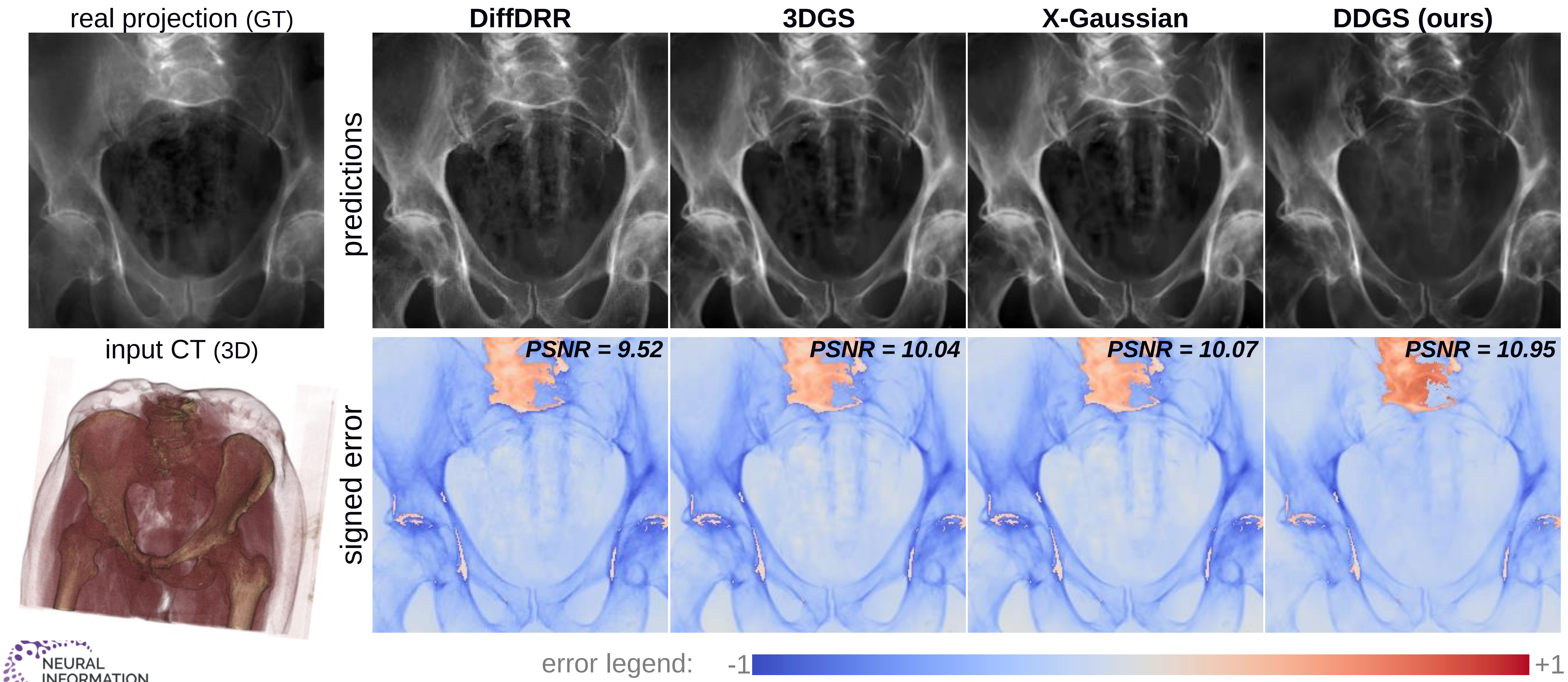
dataset: **DeepFluoro**



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DDGS-CT / results / novel view synthesis (qualitative comparison)

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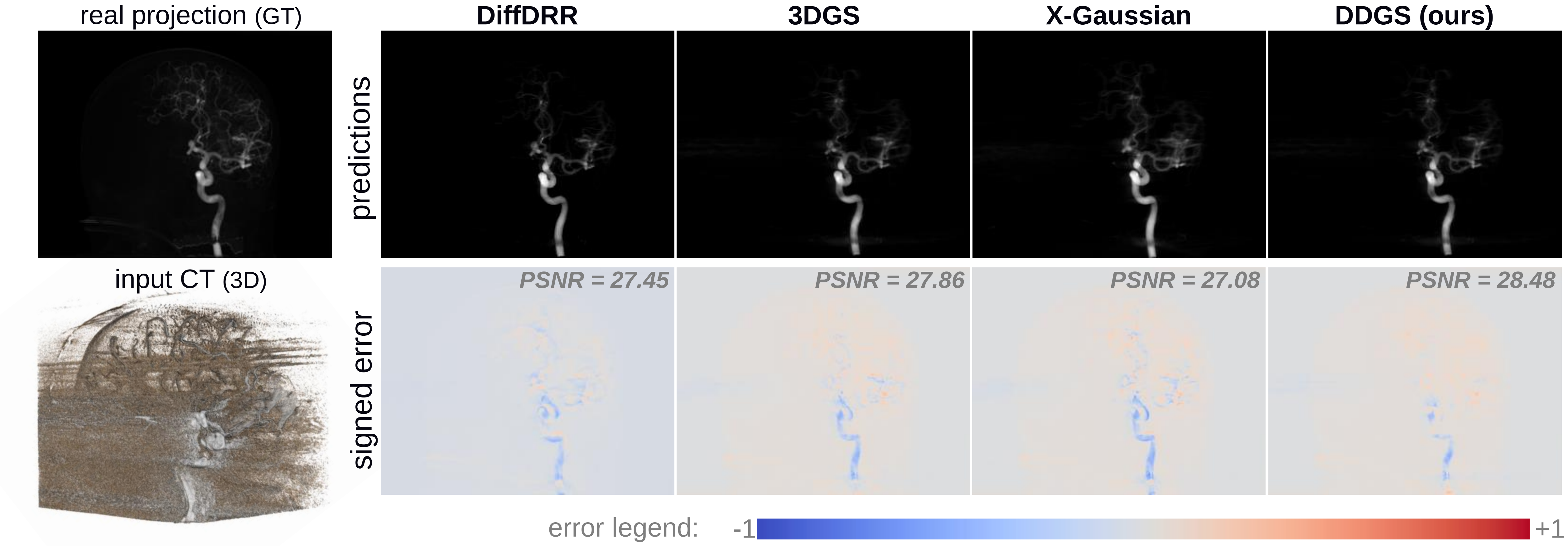
dataset: `Ljubljana`



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DDGS-CT / results / novel view synthesis (quantitative comparison)

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		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**
CTPelvic1K #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**

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DDGS-CT / results / X-ray-to-CT pose registration via iterative optimization

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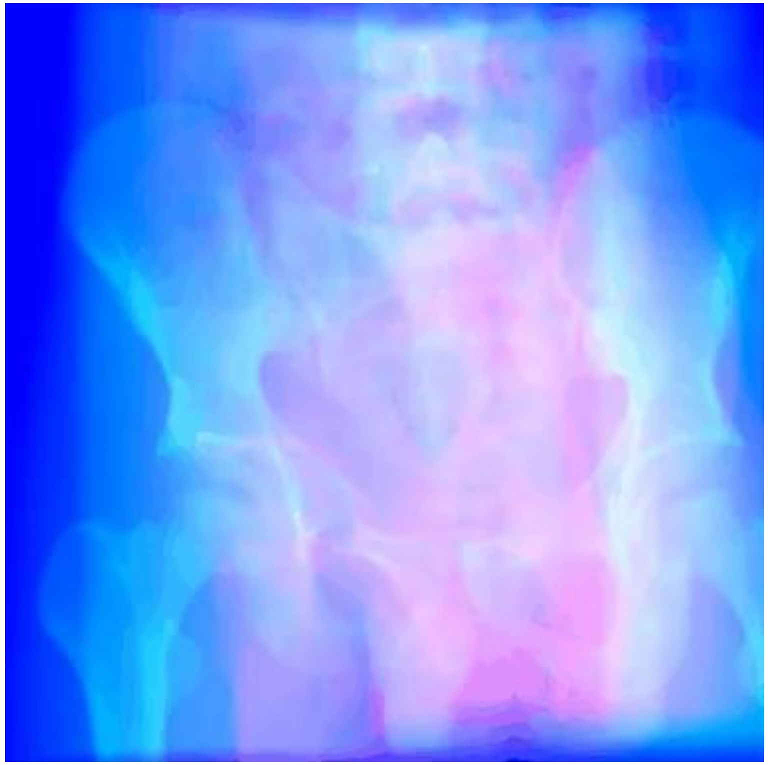
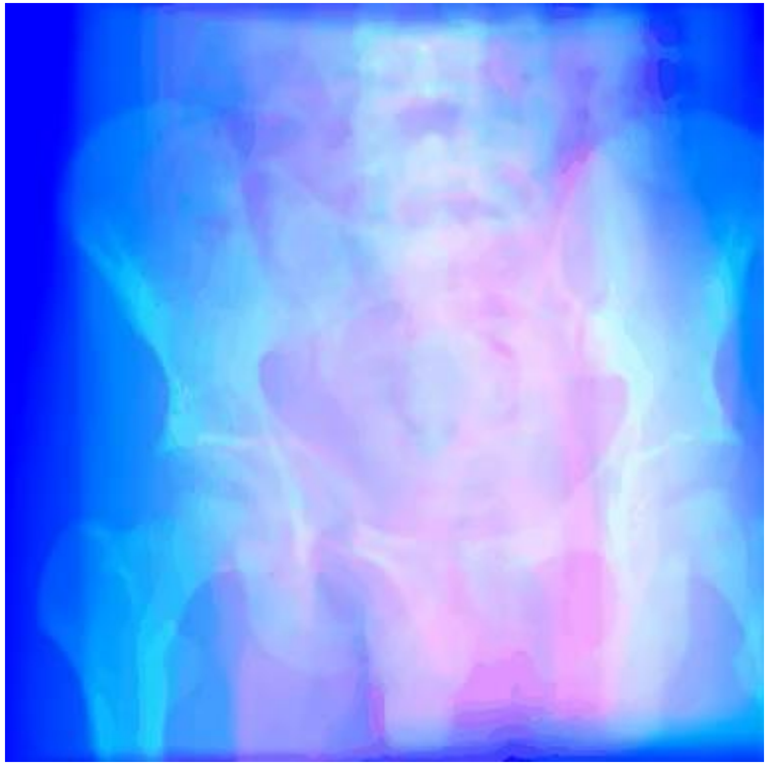
dataset: `CTPelvic1K`

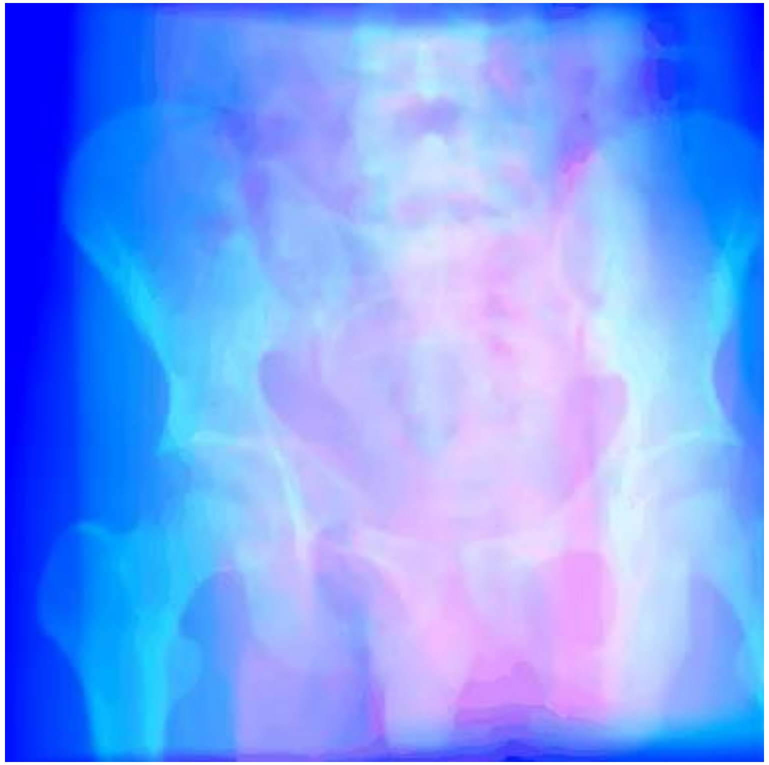
3DGS

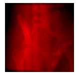


X-Gaussian



DDGS (ours)



 red channel = target real X-ray scan

 blue channel = predicted DRR

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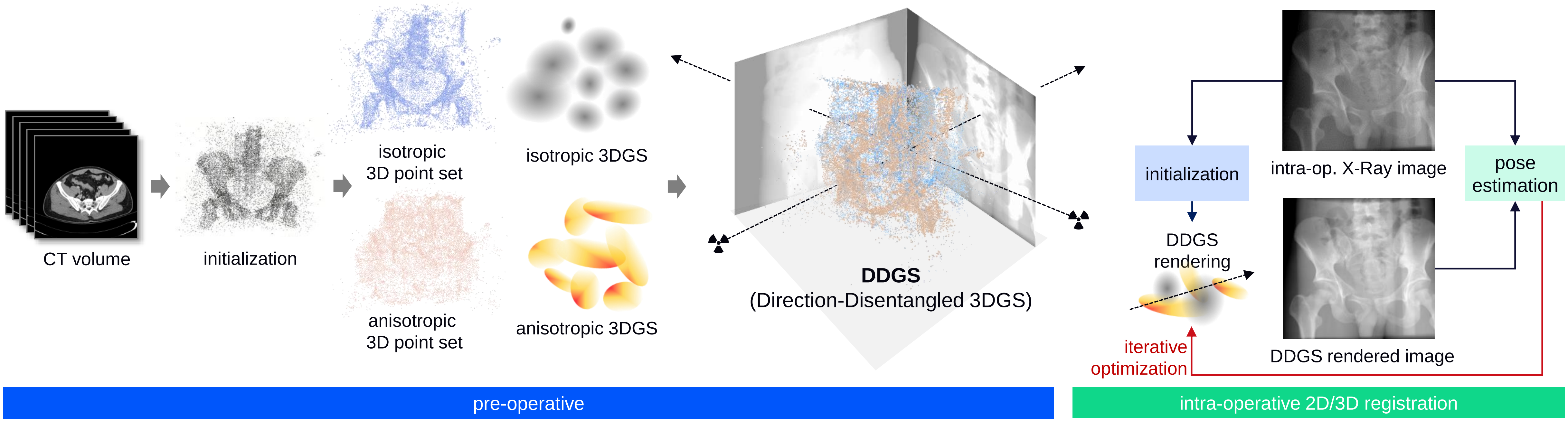
DDGS-CT / take-away / Direction-Disentangled 3DGS for DRR Rendering

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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