Shape from Blur: Recovering Textured 3D Shape and Motion of Fast Moving Objects

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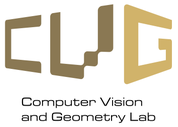
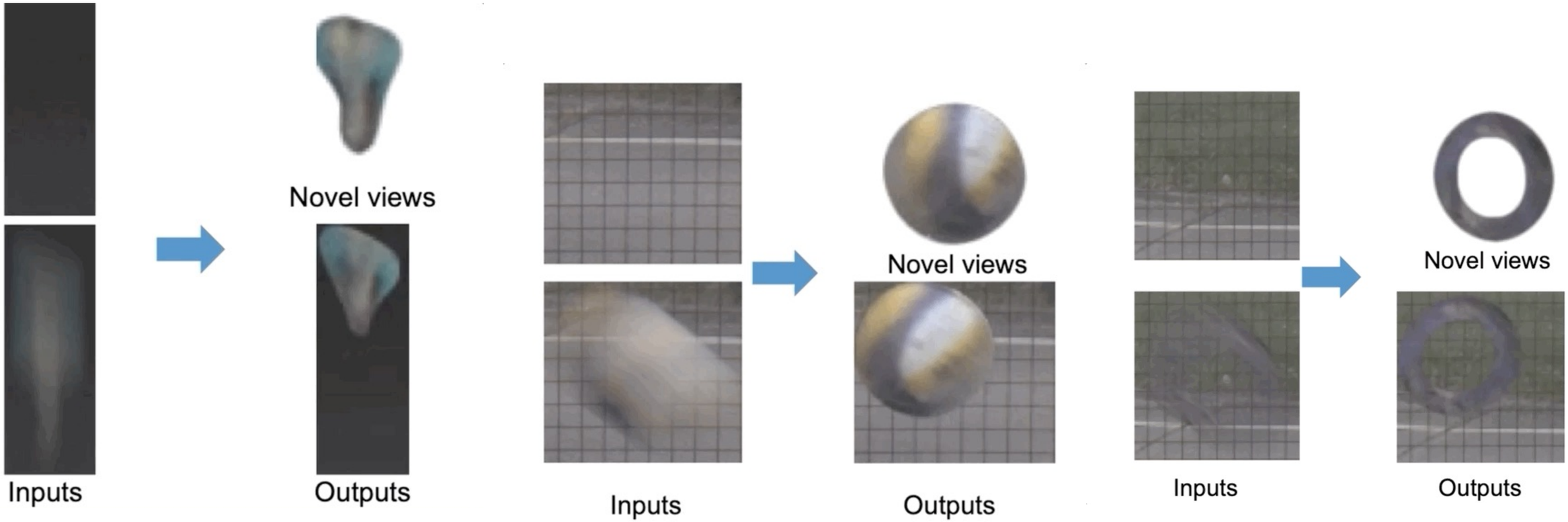


35th Conference on Neural Information Processing Systems (NeurIPS 2021)

Motivation

2D → 3D



Classical problem formulation

- Object with appearance *F* and shape *M* moving over static background *B*
- *H* - the blur caused by motion along trajectory

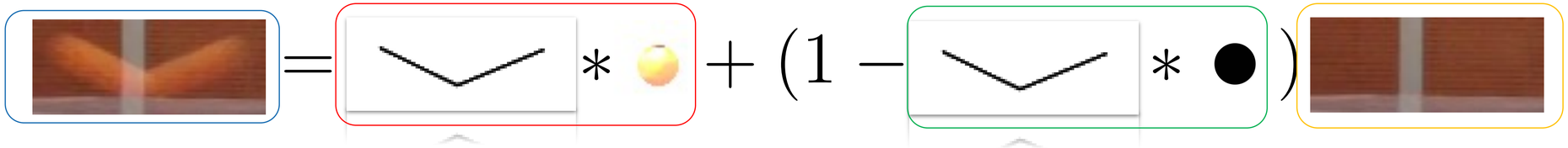
Blurred object

Visibility map

Foreground

Background

$$I = H * F + (1 - H * M) B$$

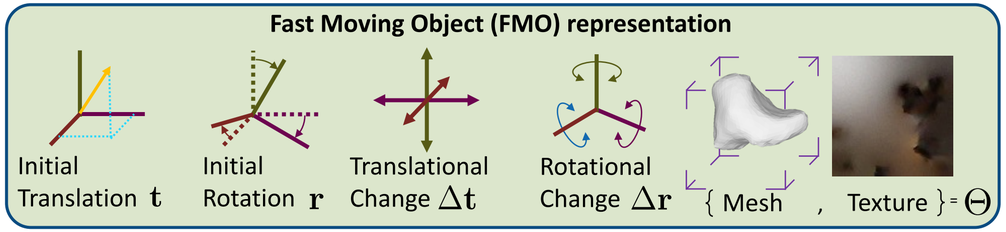


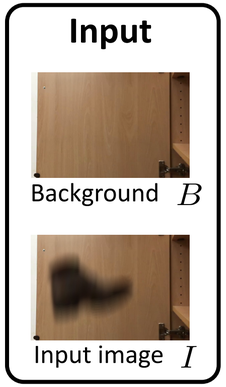
- Shape from Blur generalization to 3D:

$$\hat{I}(\cdot) = \int_0^1 \mathcal{R}_F\big(\mathcal{M}(\Theta, \mathbf{r}+\tau\cdot\Delta\mathbf{r}, \mathbf{t}+\tau\cdot\Delta\mathbf{t})\big)\mathrm{d}\tau + \Big(1 - \int_0^1 \mathcal{R}_S\big(\mathcal{M}(\Theta, \mathbf{r}+\tau\cdot\Delta\mathbf{r}, \mathbf{t}+\tau\cdot\Delta\mathbf{t})\big)\mathrm{d}\tau\Big)\cdot B$$

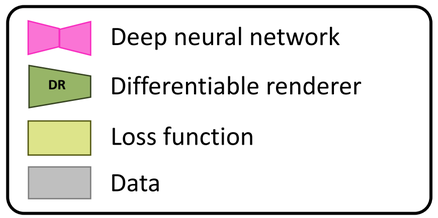
Method overview

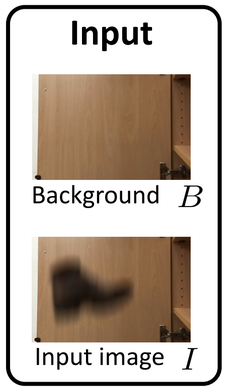
Contribution: Novel FMO deblurring method that for the first time jointly estimates from a **single input** image the 3D shape, texture, and motion of an object (initial 6-DoF pose, 3D translation and 3D rotation).

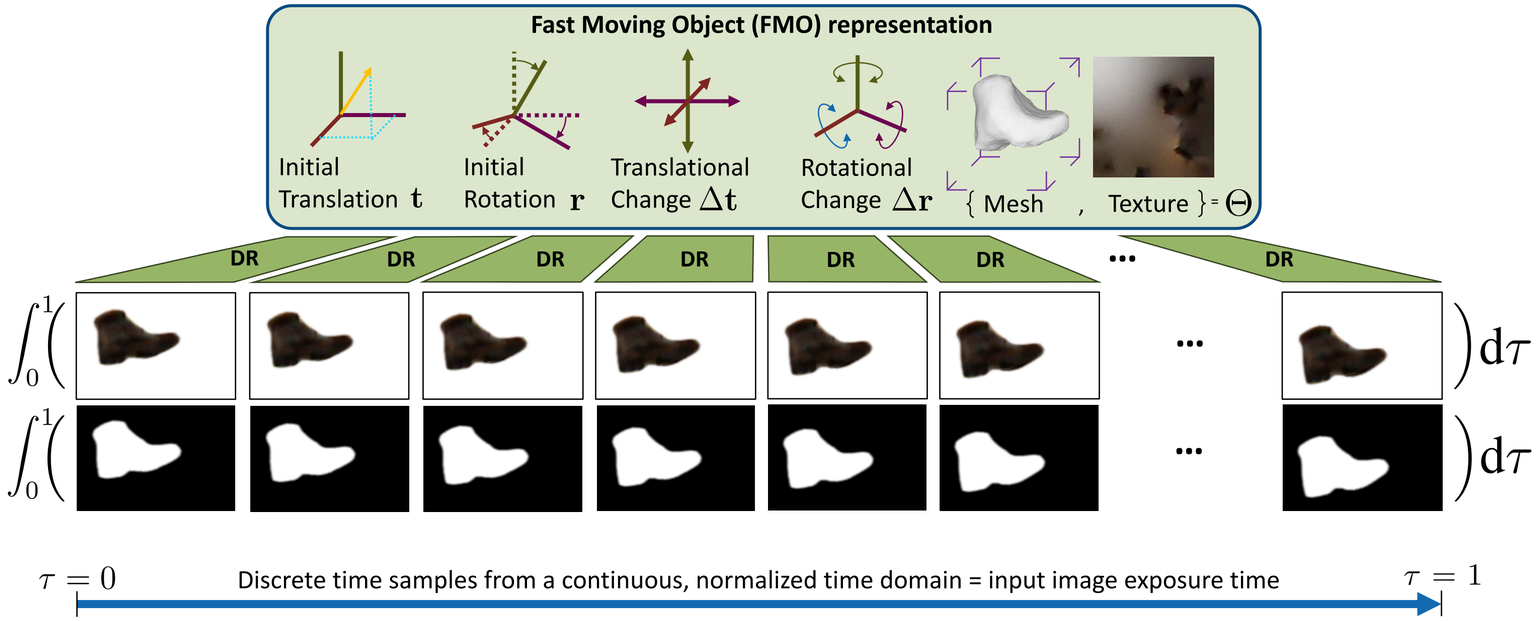




Method overview







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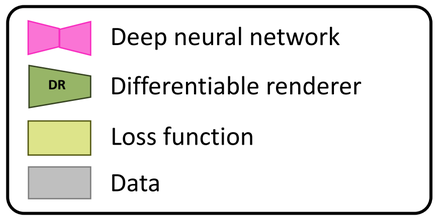
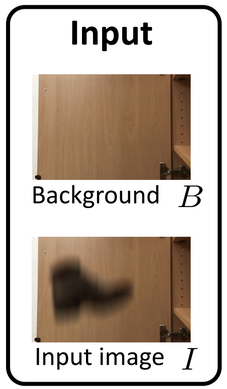
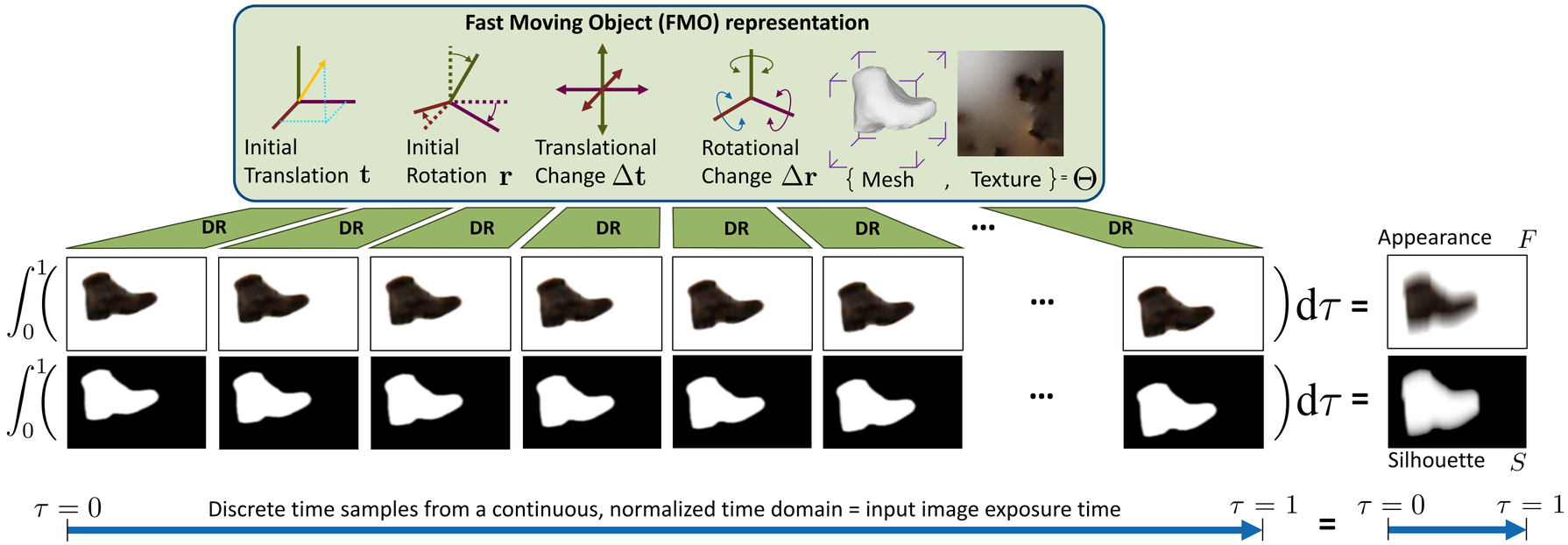
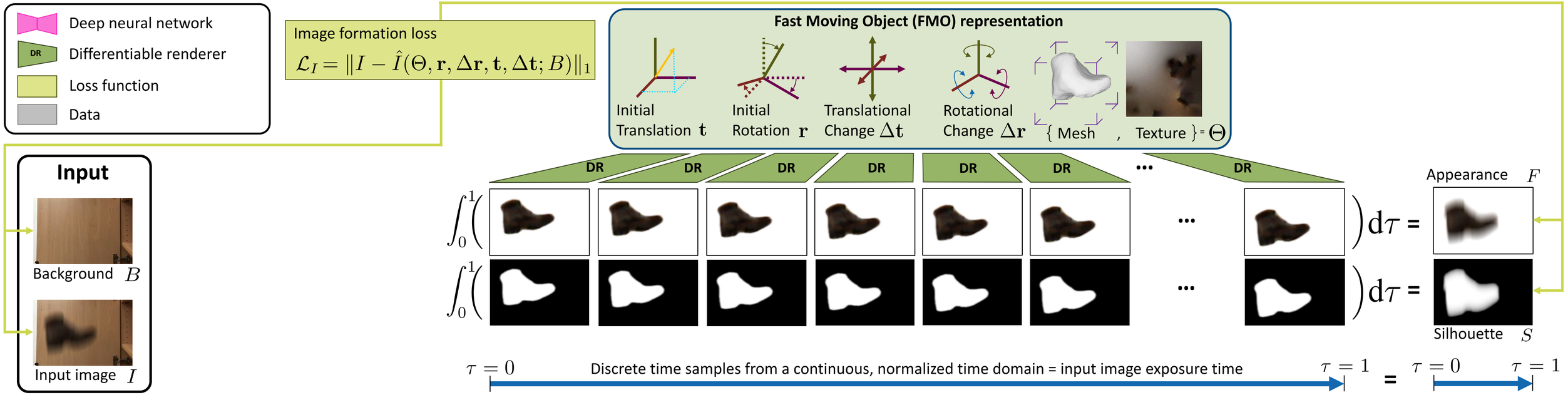


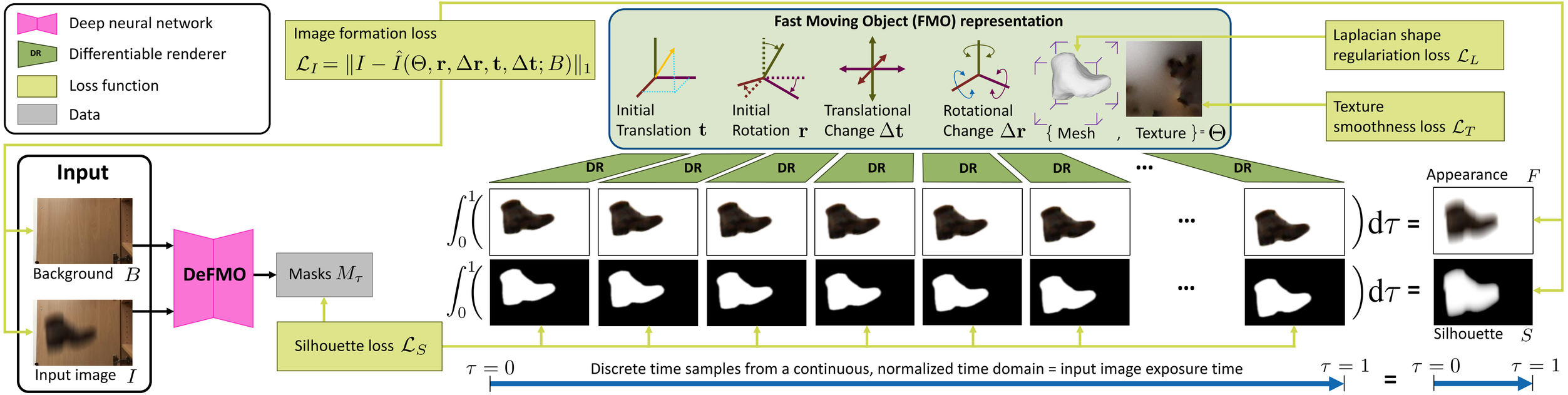




Method overview



Method overview

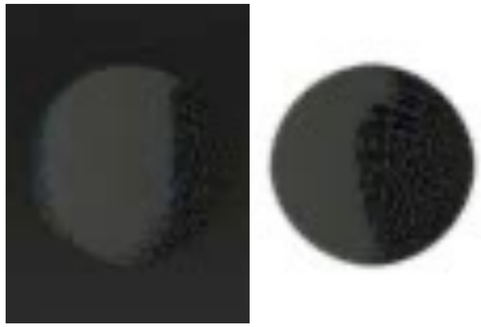


”DeFMO”: [11] Rozumnyi et al. “DeFMO: Deblurring and Shape Recovery of Fast Moving Objects”, CVPR 2021

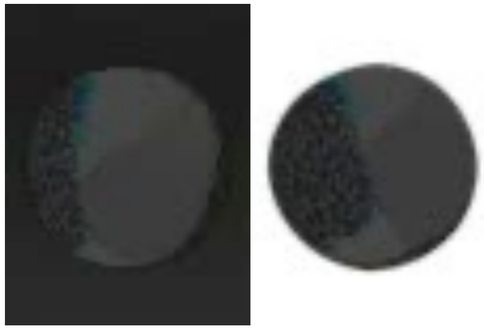
Loss optimization

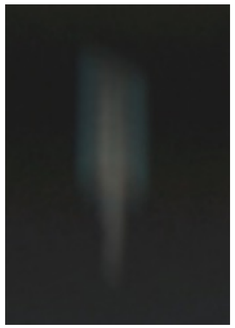
Torus

Sphere 1



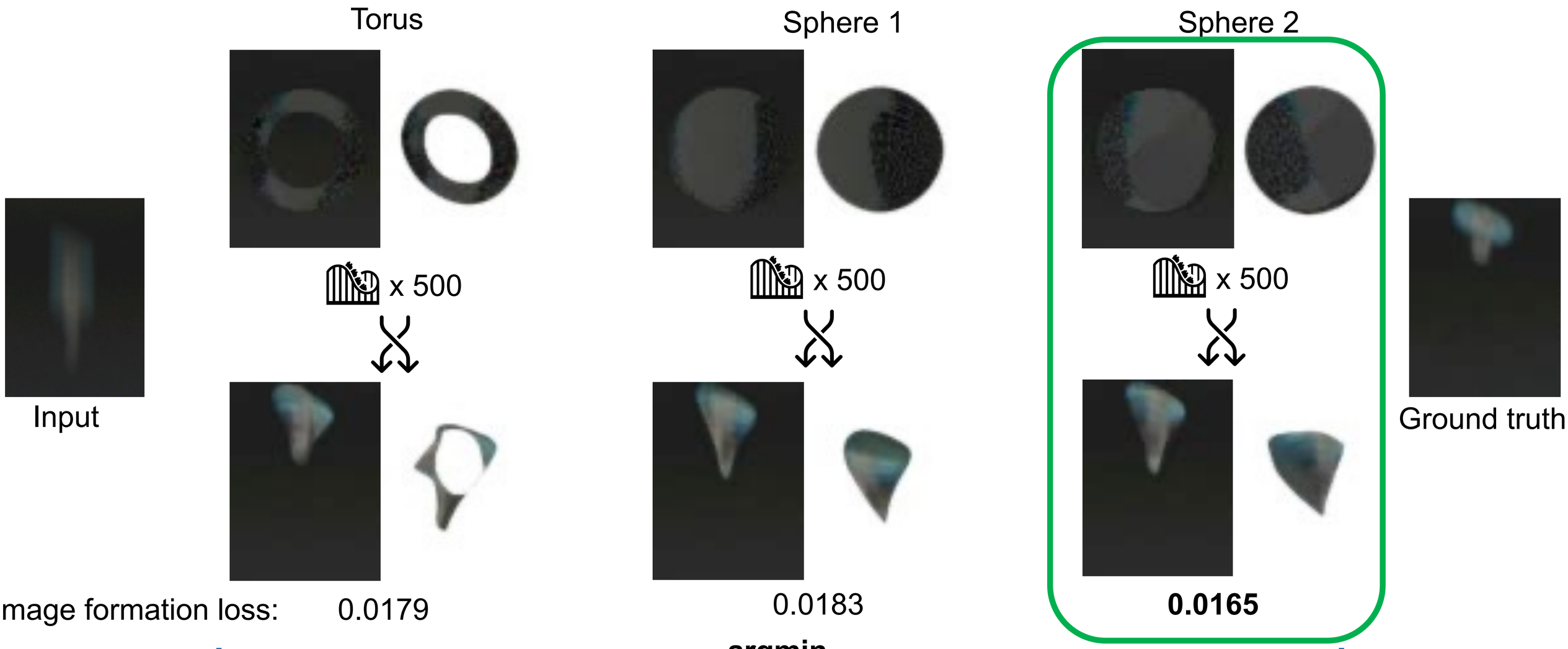
Sphere 2



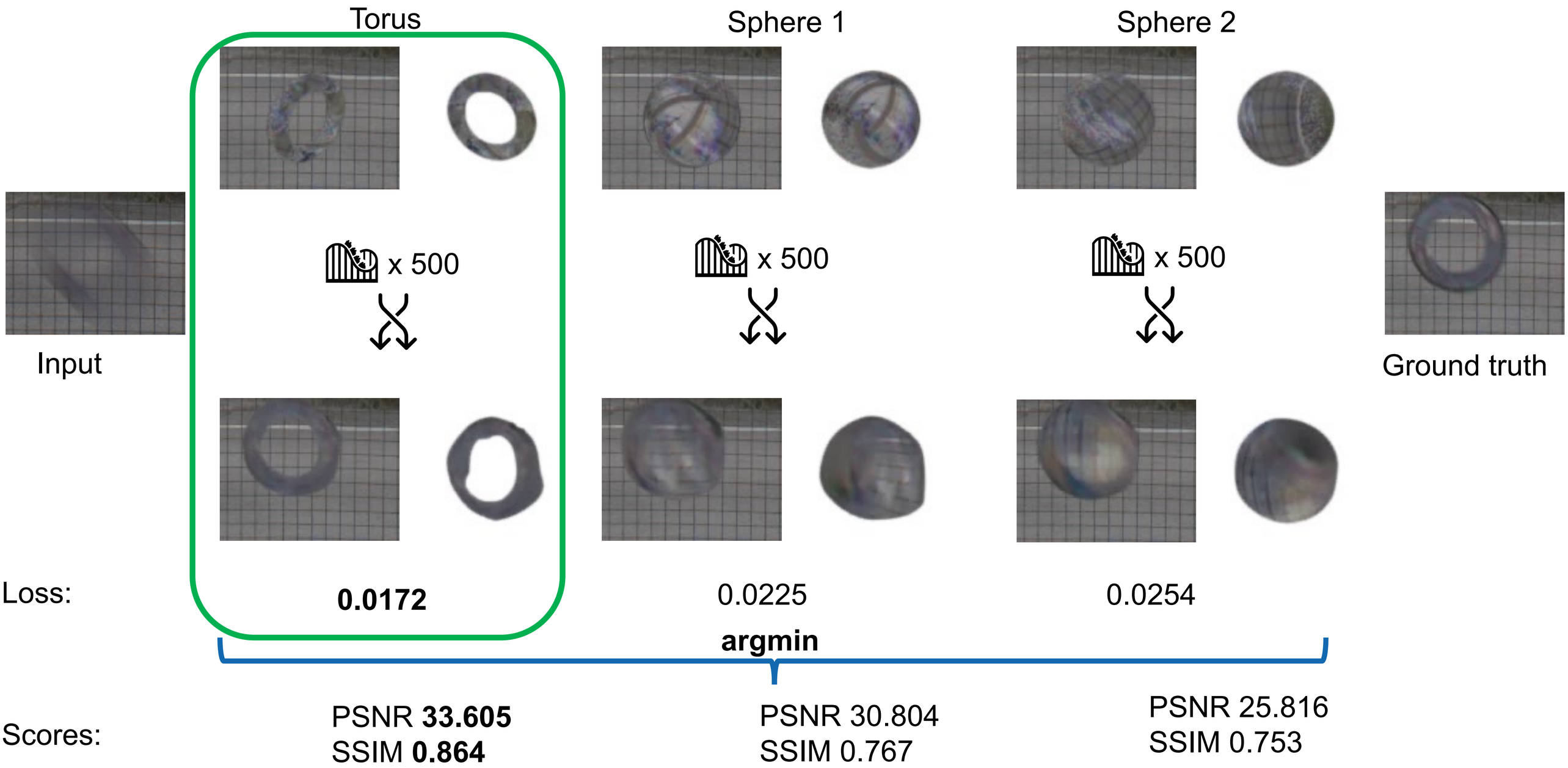


Input

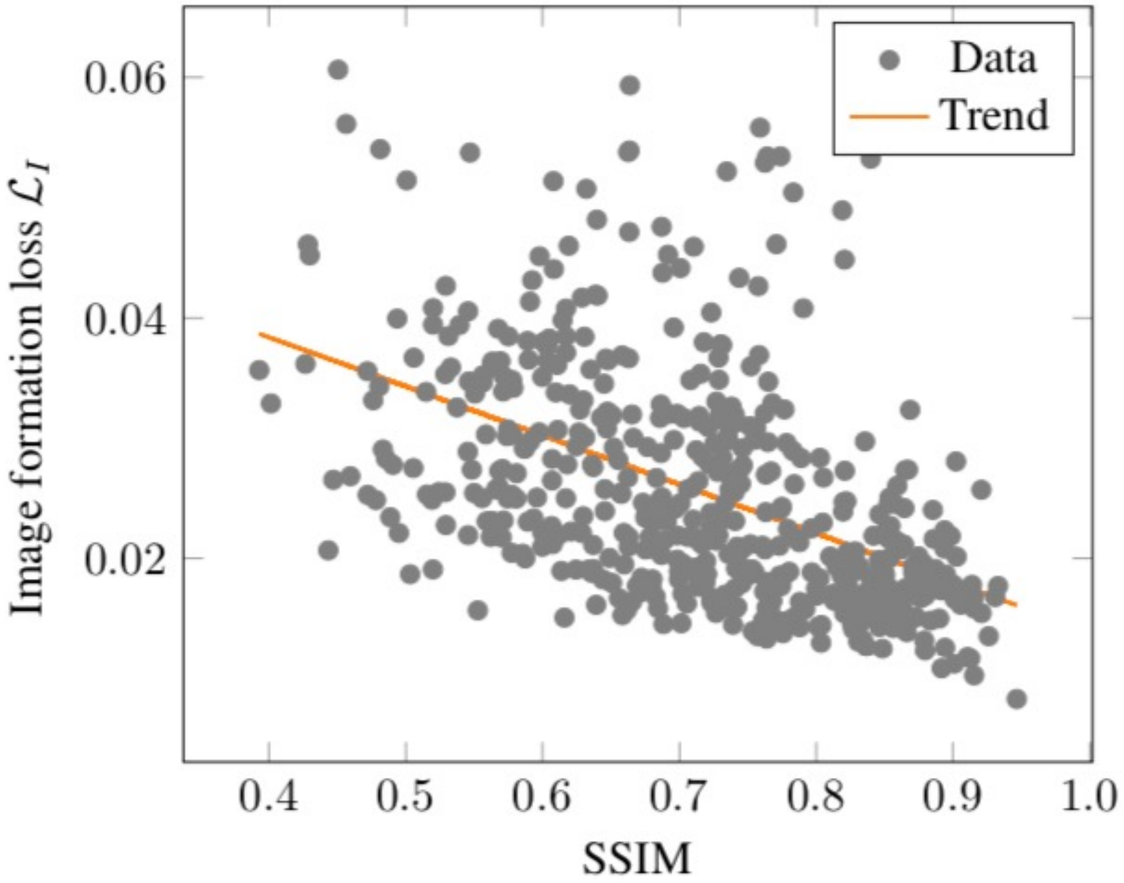
Loss optimization

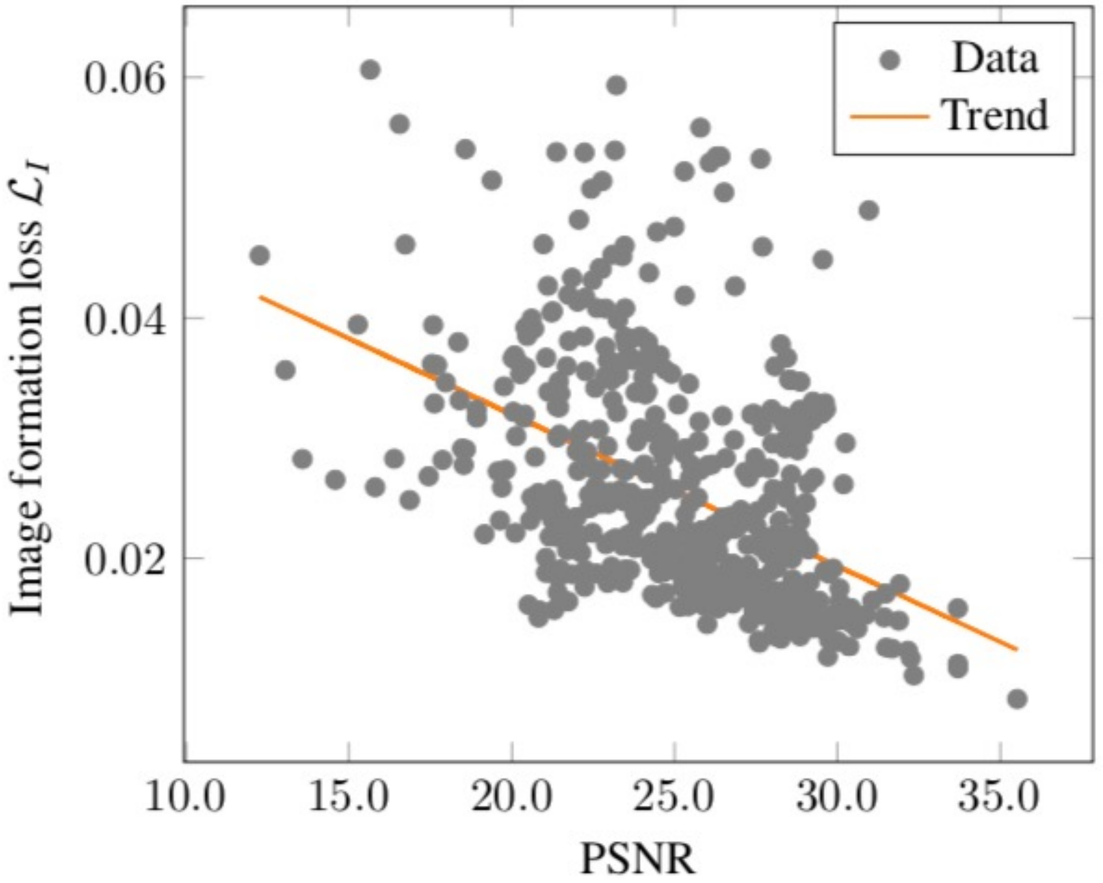


Loss optimization

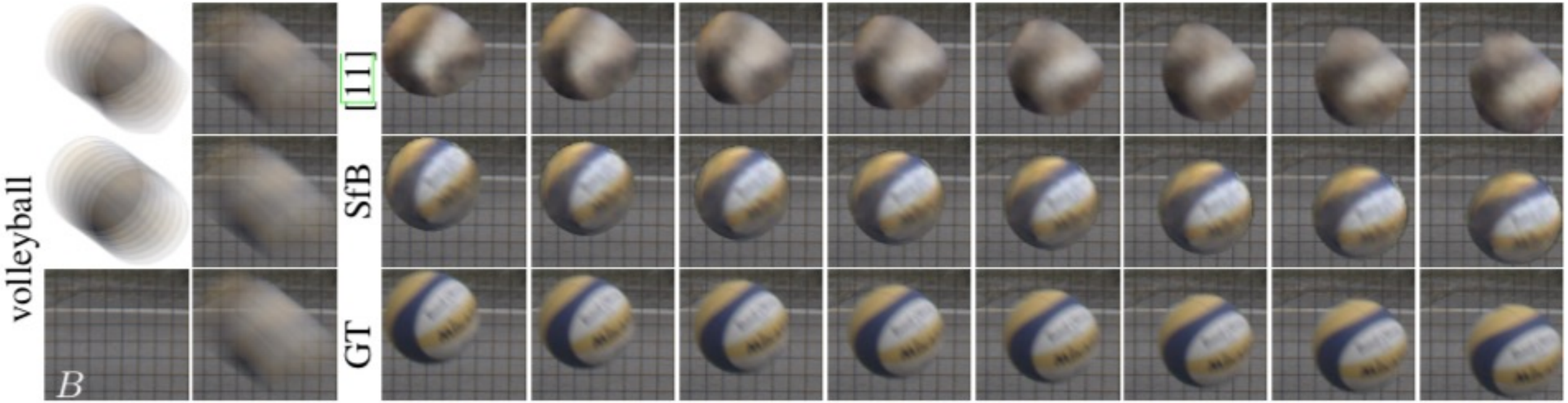


Correlation

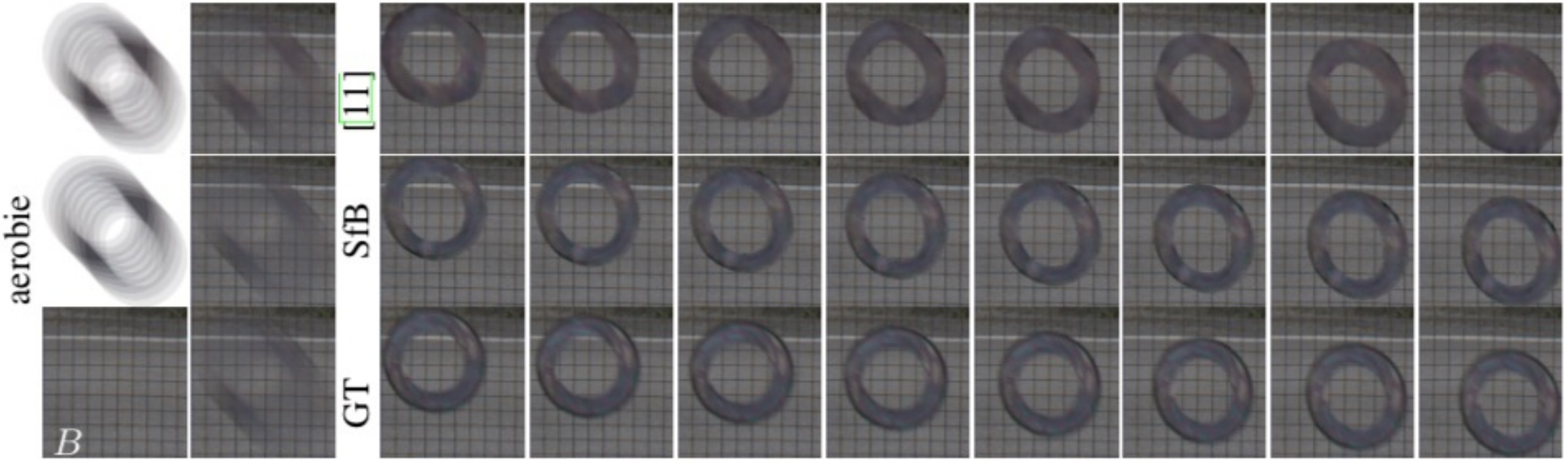




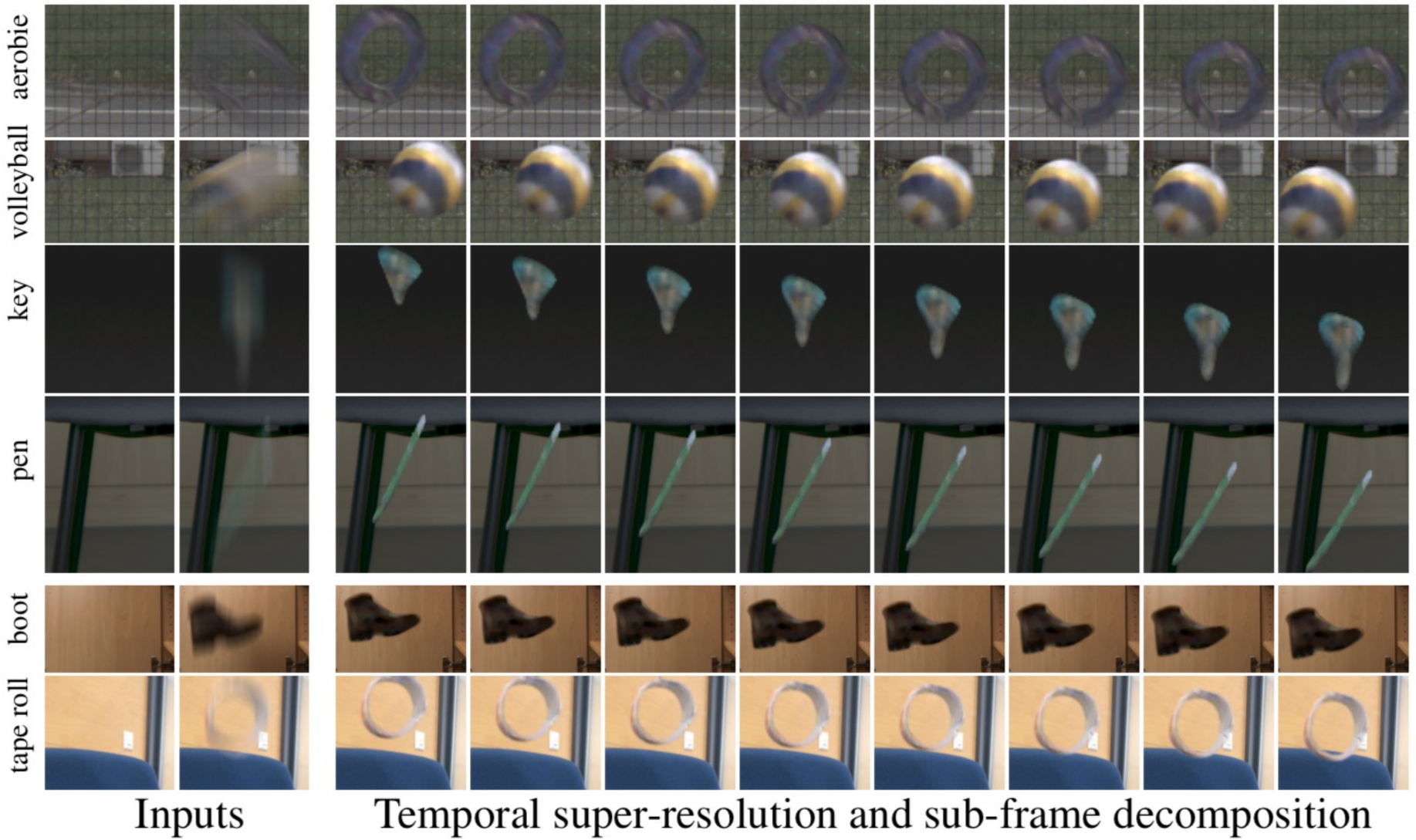
Results



Results



Results


aerobie
volleyball
key
pen
boot
tape roll
Inputs
Temporal super-resolution and sub-frame decomposition

Qualitative results

Novel views

Inputs

Outputs

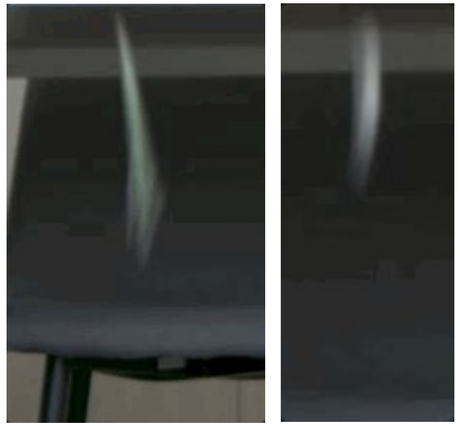
DeFMO
(current SOTA)

Ground truth

Benchmark evaluation

Hard | Medium | Easy

Method	Falling Objects [21]			TbD-3D Dataset [22]			TbD Dataset [18]		
	TIoU↑	PSNR↑	SSIM↑	TIoU↑	PSNR↑	SSIM↑	TIoU↑	PSNR↑	SSIM↑
Jin et al. [3]	N / A	23.54	0.575	N / A	24.52	0.590	N / A	24.90	0.530
DeblurGAN [2]	N / A	23.36	0.588	N / A	23.58	0.603	N / A	24.27	0.537
TbD [18]	0.539	20.53	0.591	0.598	18.84	0.504	0.542	23.22	0.605
TbD-3D [22]	0.539	23.42	0.671	0.598	23.13	0.651	0.542	25.21	**0.674**
DeFMO [11]	0.684	26.83	0.753	0.879	26.23	0.699	0.550	25.57	0.602
SfB (ours)	**0.701**	**27.18**	**0.760**	**0.921**	**26.54**	**0.722**	**0.610**	**25.66**	0.659



various shapes
complex textures

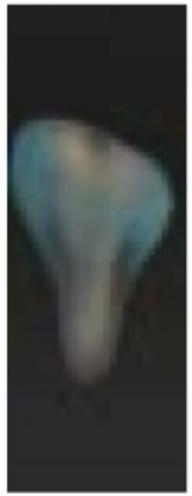
mostly spherical
complex textures

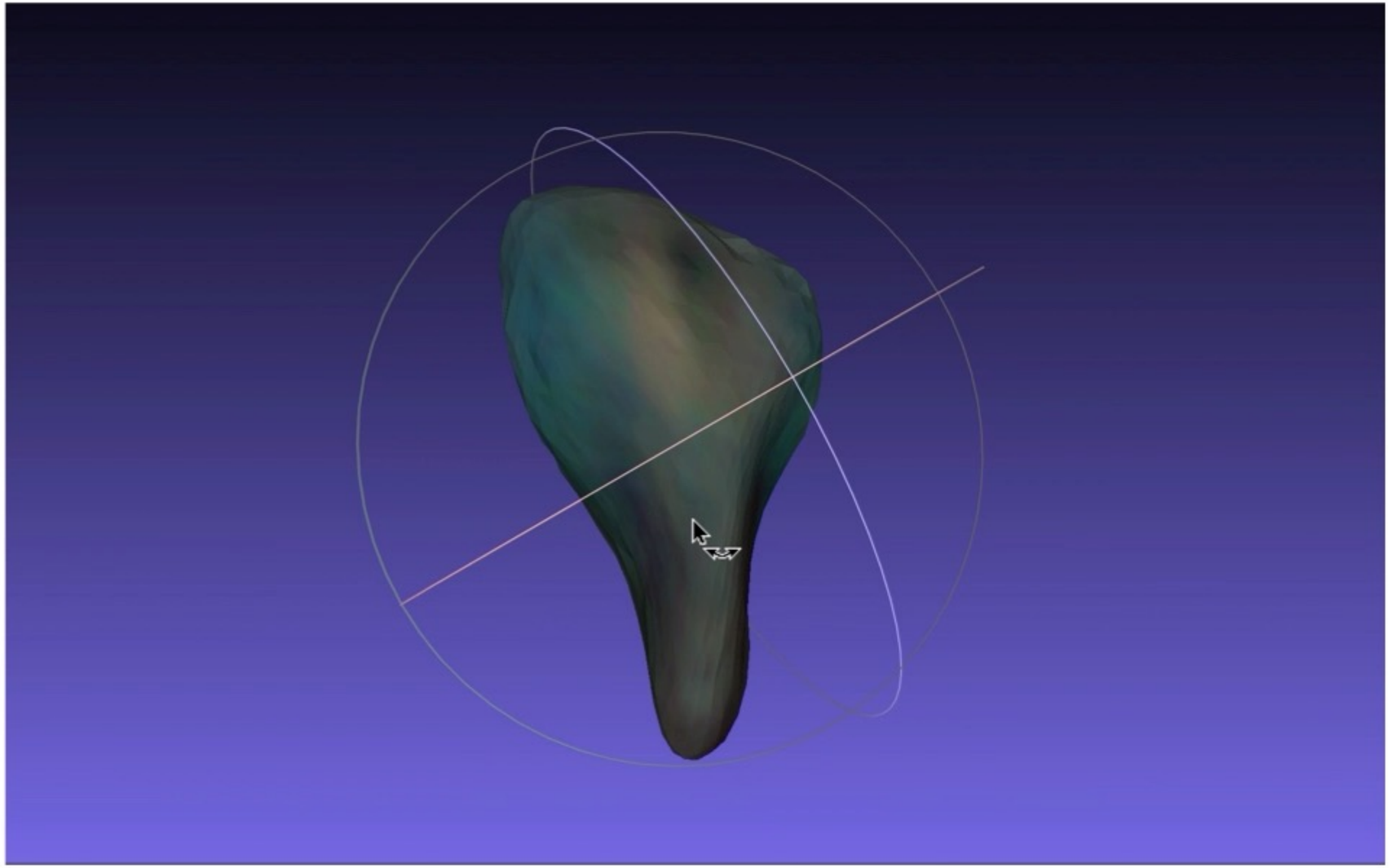
mostly spherical
uniform textures

Novel views

Input

Output

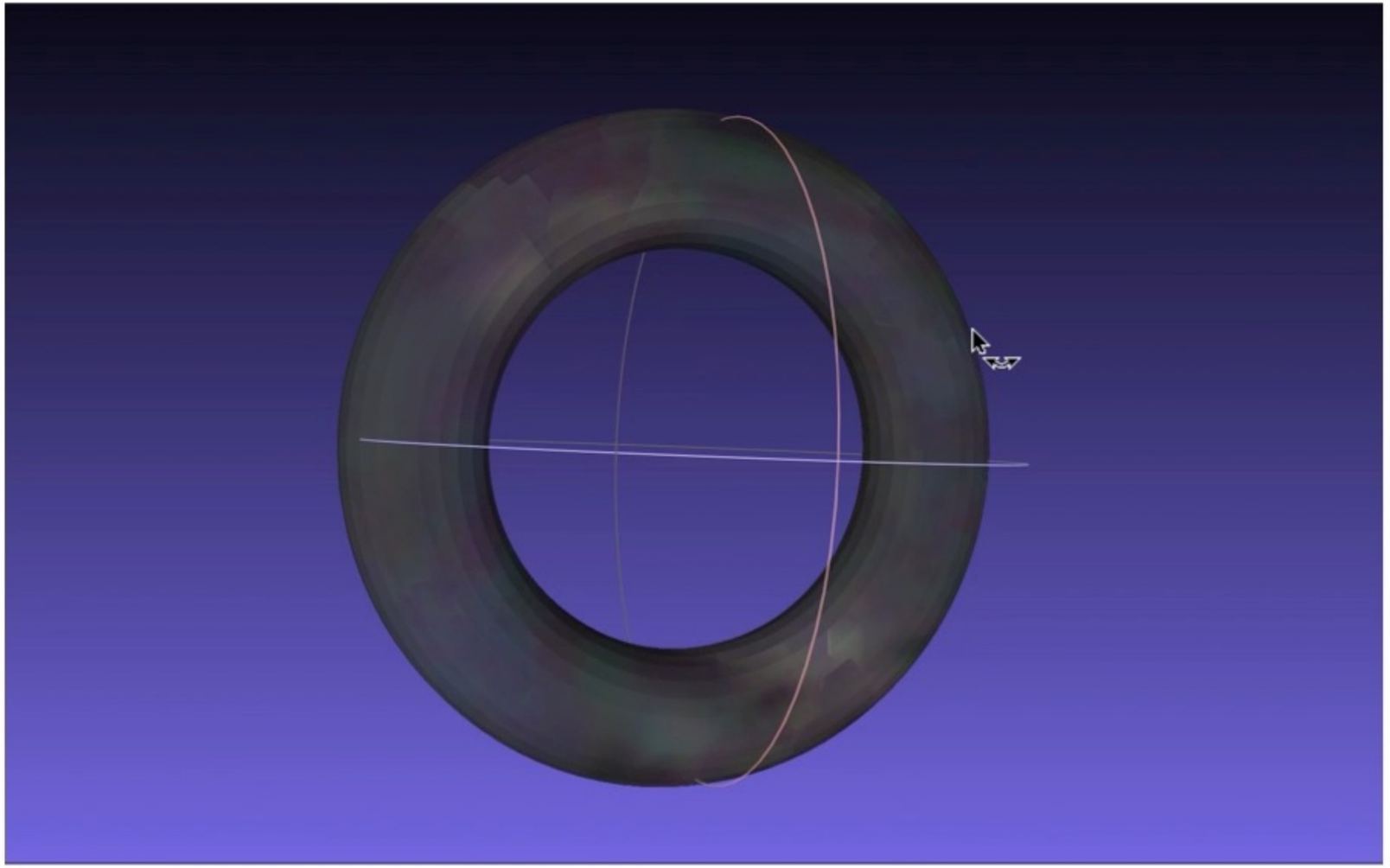




Novel views

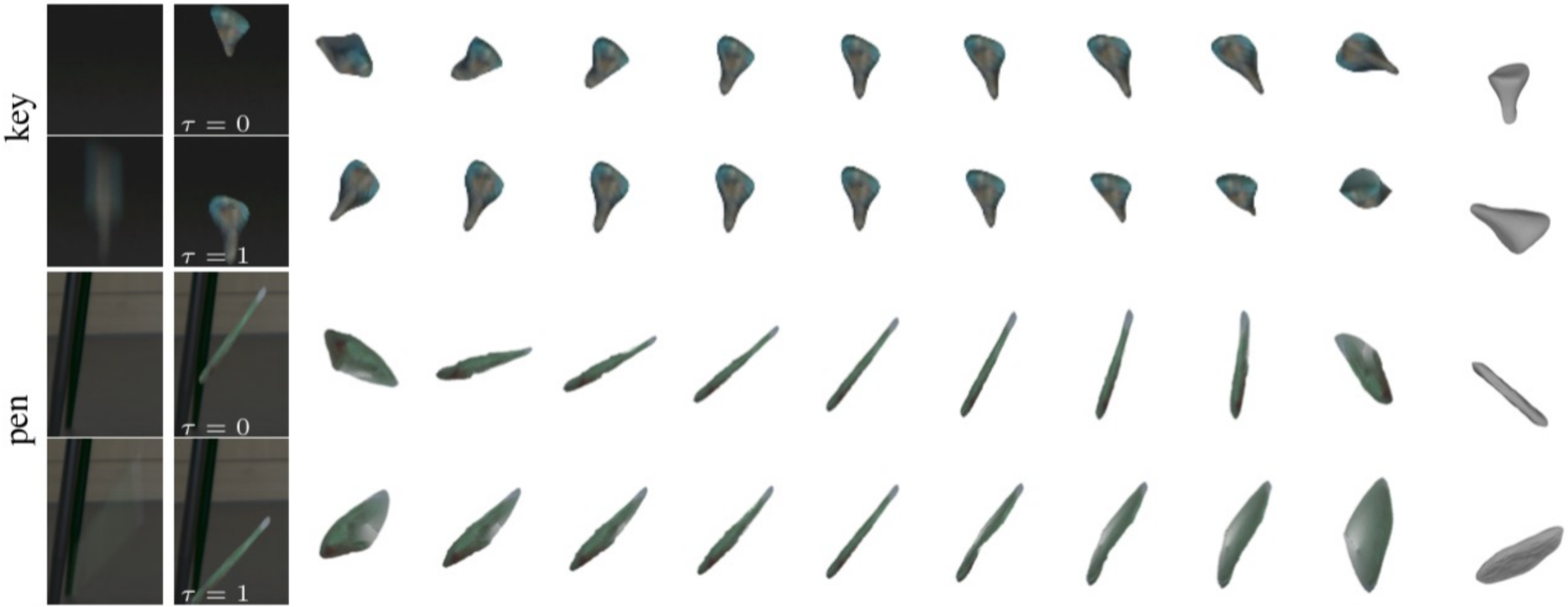
Input

Output



Limitations

- Prototype shape deformation – the shape often remains unchanged along unobserved directions (pen).
- Extreme camera motion.



Conclusion

- SfB is the first solution to the problem of **3D shape** and **motion** estimation from a **single blurry input**.
- We set a new state of the art on **2D** fast moving object **deblurring**.
- Open source: https://github.com/rozumden/ShapeFromBlur