DiffFNO: Diffusion Fourier Neural Operator
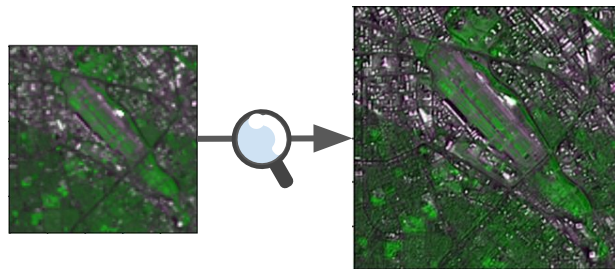
Xiaoyi Liu[1], Hao Tang[2]

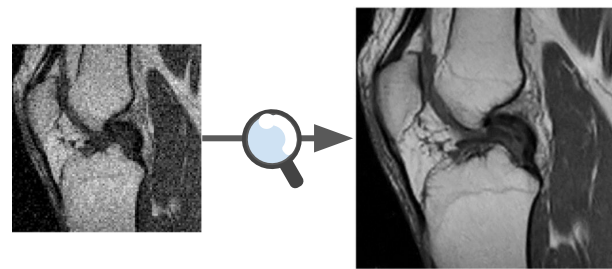[1]Washington University in St Louis, [2]Peking University

Super Resolution
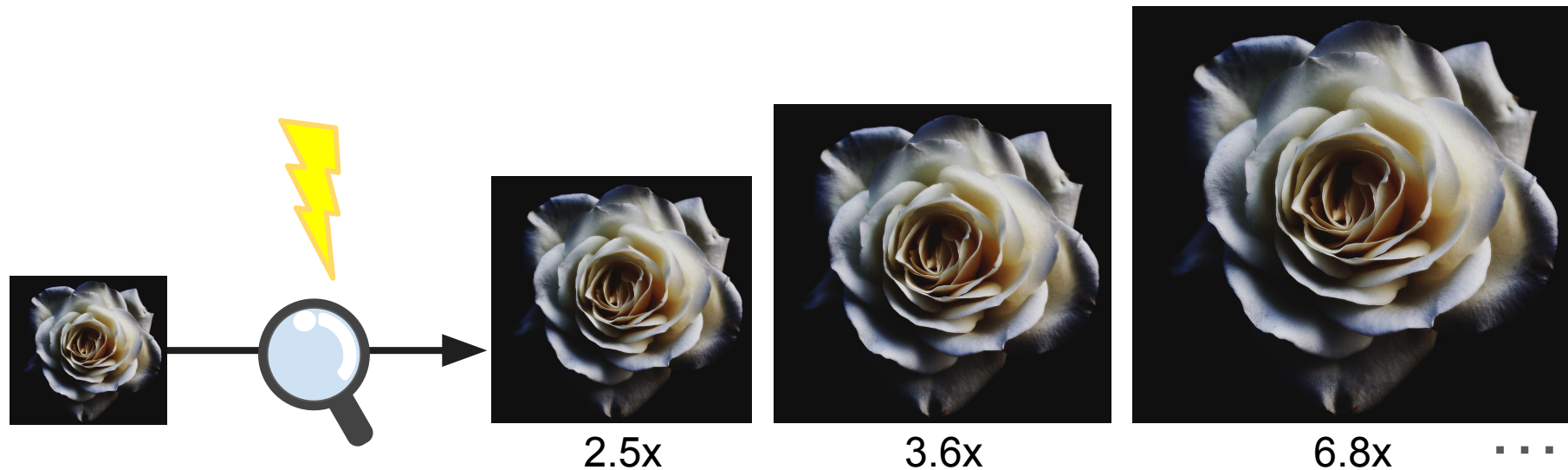

Media & Gaming

Remote Sensing

Medical Imaging

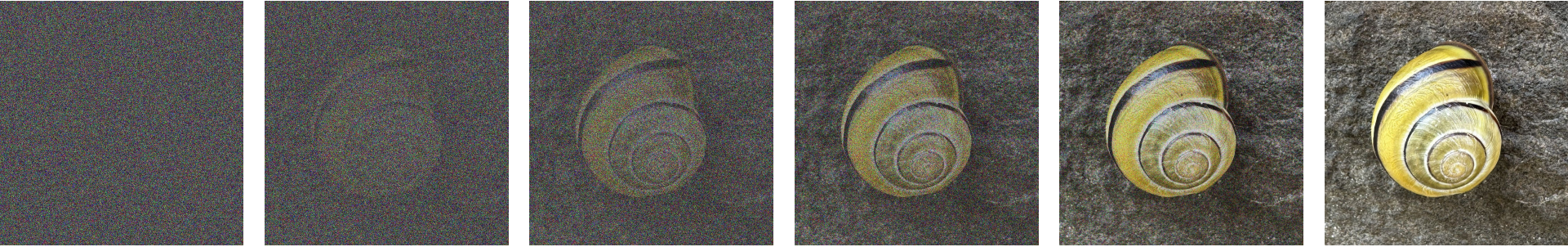Also: Art restoration, E-commerce, Autonomous vehicles

Arbitrary-Scale Super Resolution

2.5x   3.6x   6.8x   ...

Related Work I: Diffusion Model

Forward

Reverse

Related Work I: Diffusion Model

Forward

Reverse

LR Image + Noise

HR Image

Related Work II: Operator Learning

Fixed-size

Vectors

Continuous
Representation

Function

In-between?

Related Work II: Operator Learning

Fixed-size

Vectors

Continuous
Representation

Function

In-between?

. . .

Different
Resolutions
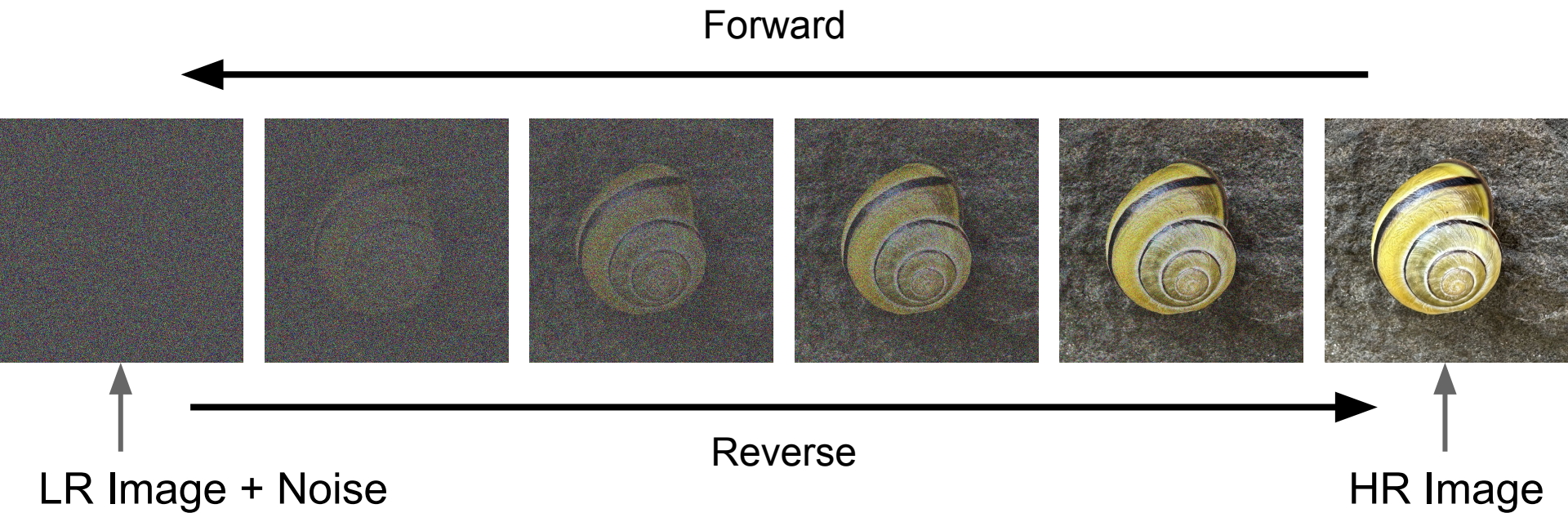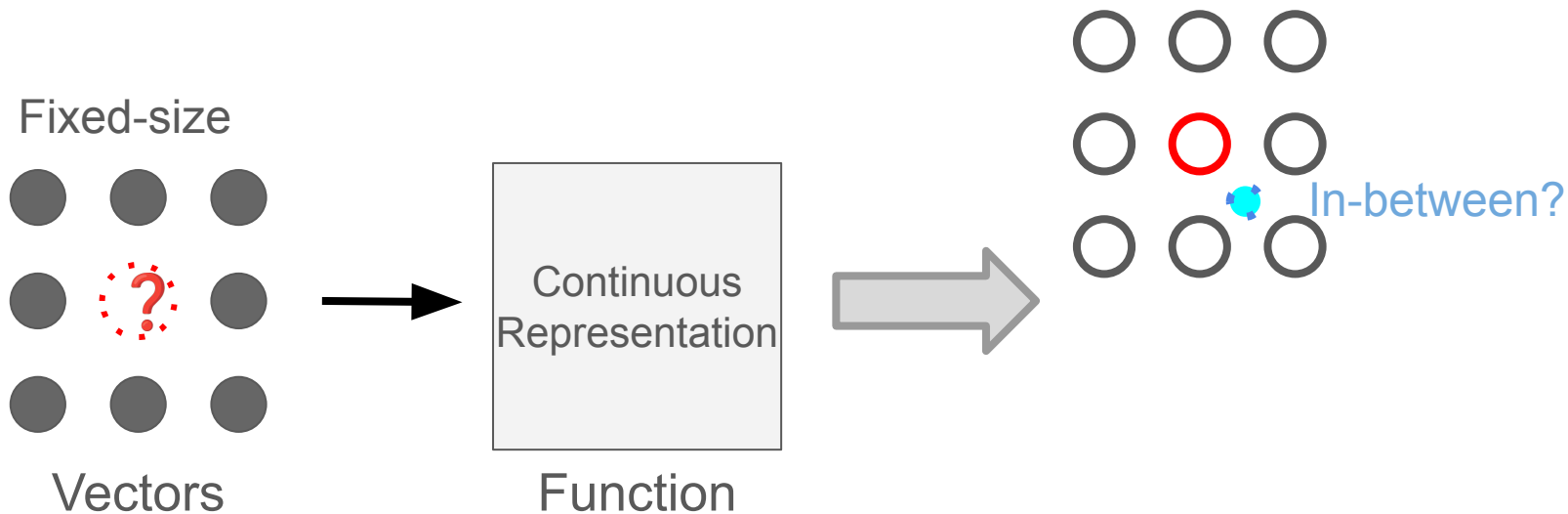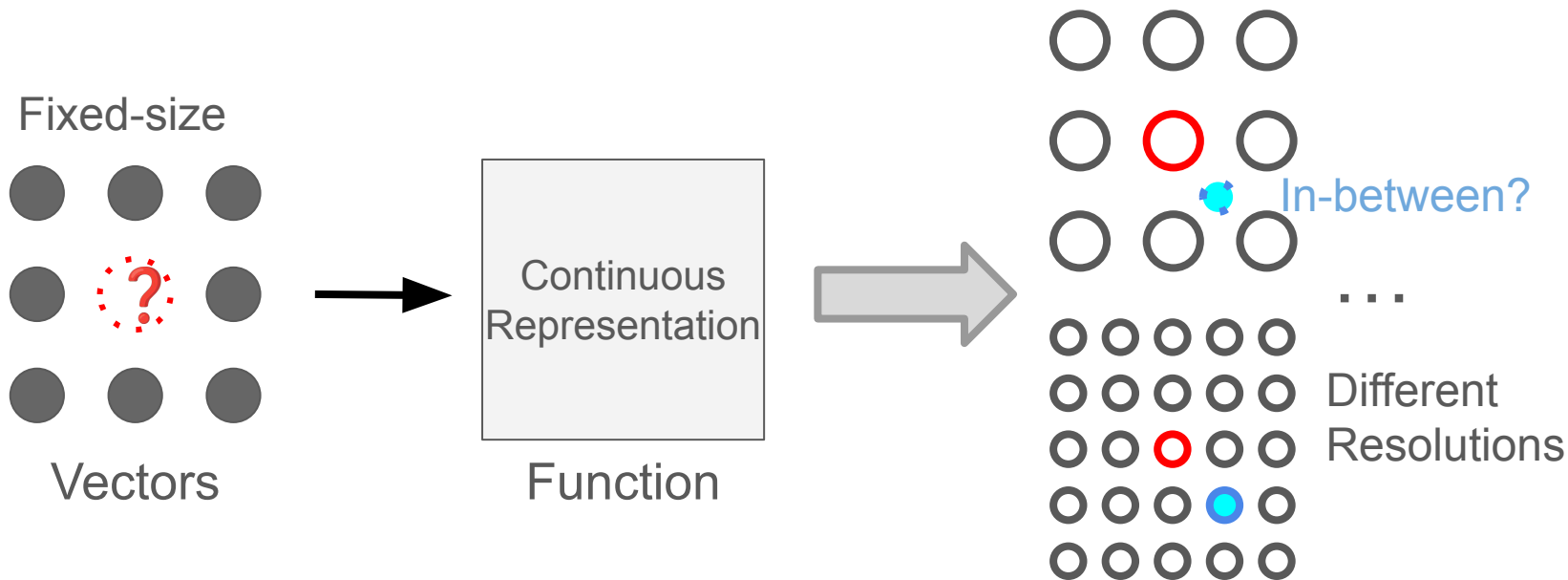
LR Image

Diffusion?

HR Image

Our Approach

Operator Learning

Upsample

Diffusion

Refinement
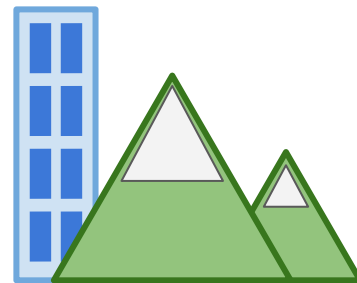
LR Image

HR Image
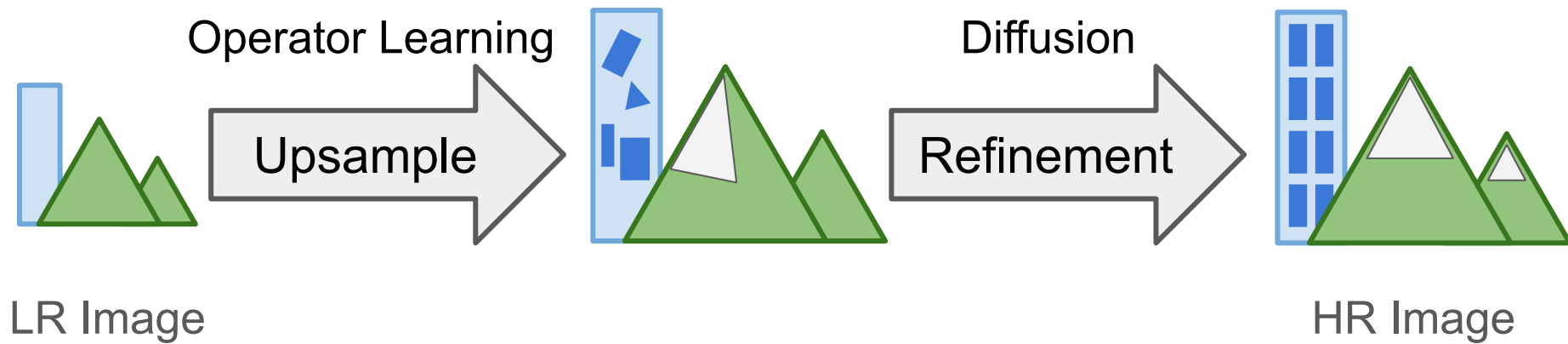
Why DiffFNO?

Ours

Ground Truth (9.6x)

CIT Building, Brown University

Fourier Neural Operator

Low Frequency ✅

High Frequency 🤔

$$\mathcal{F}\mathcal{K}\mathcal{F}^{-1}$$
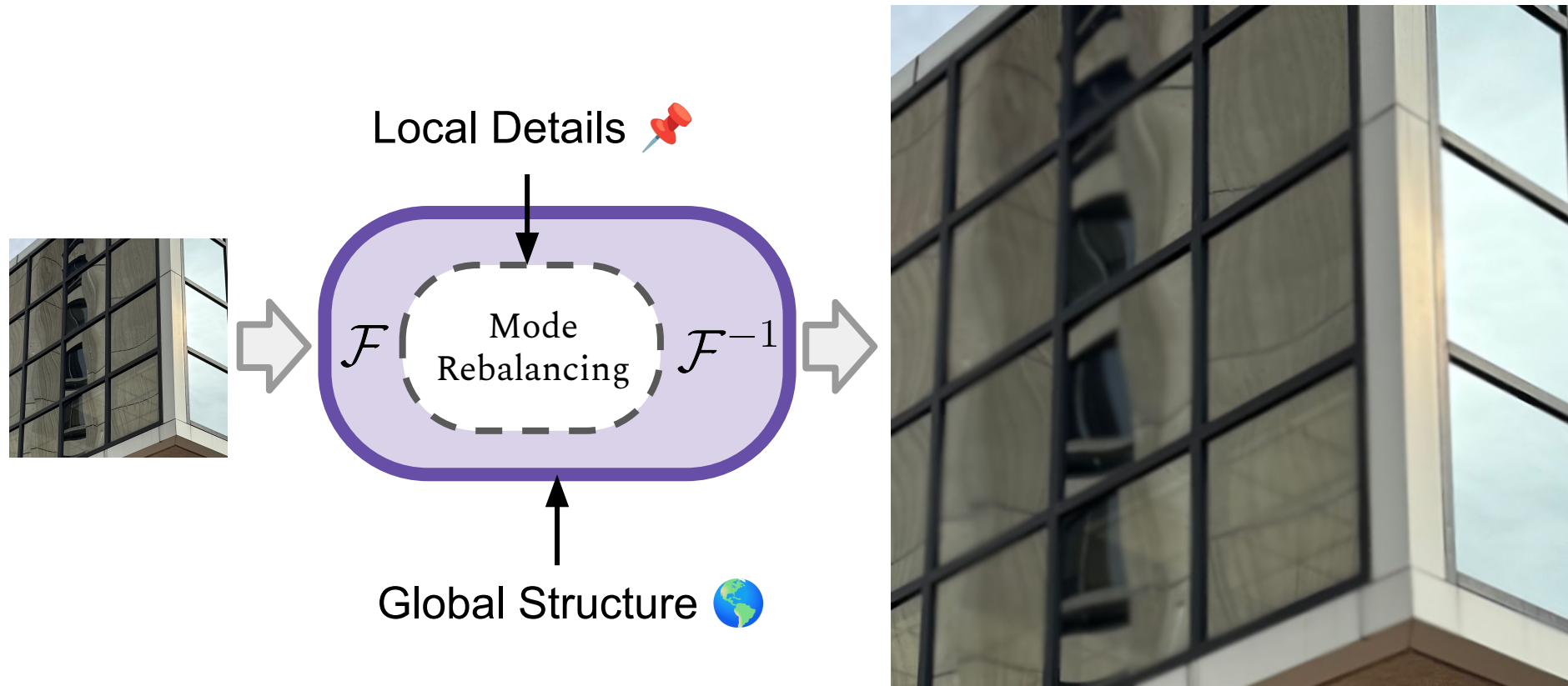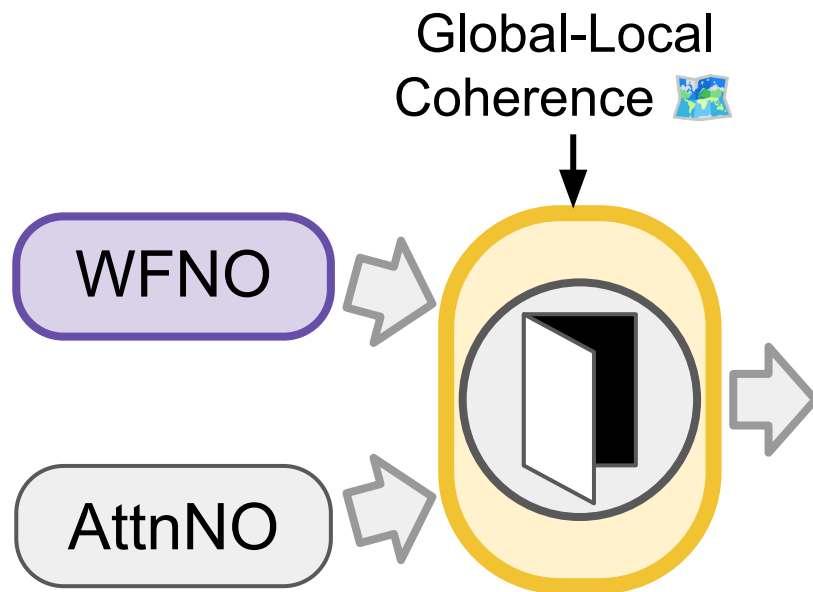
Weighted Fourier Neural Operator (WFNO)

Gated Fusion Mechanism

Global-Local
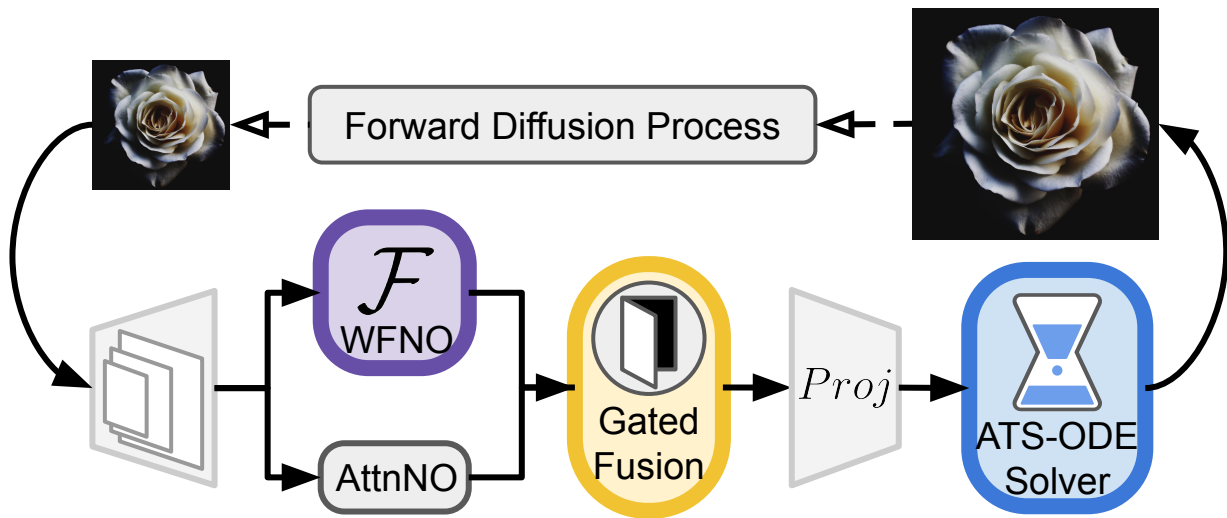Coherence 🗺️

WFNO

AttnNO

Adaptive Time-Stepping ODE Solver
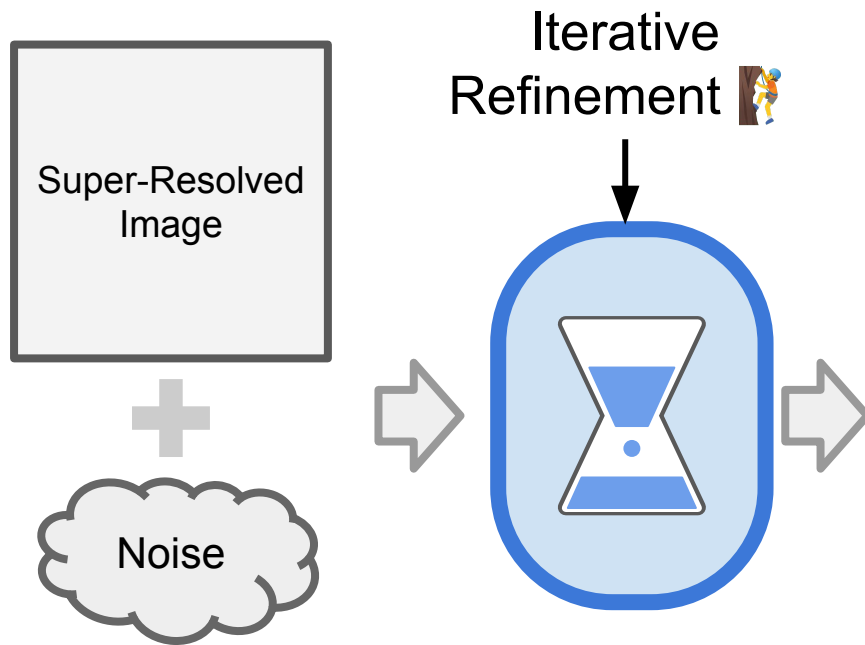
DiffFNO
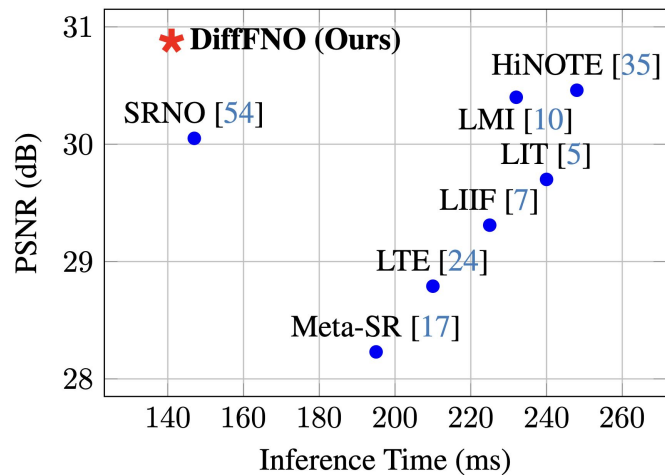
(a) **PSNR and inference time for ×4 super-resolution**

Model	×2		×3		×4		×6		×8		×12	
	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
EDSR-MetaSR [17]	33.32	0.913	30.10	0.800	28.23	0.830	26.10	0.792	24.77	0.742	23.95	0.720
EDSR-LTE [24]	33.83	0.921	30.50	0.880	28.79	0.852	26.55	0.800	25.05	0.760	24.20	0.736
EDSR-LIIF [7]	34.36	0.925	30.94	0.885	29.31	0.855	27.02	0.814	25.44	0.771	24.32	0.743
EDSR-LIT [5]	34.81	0.928	31.39	0.890	29.70	0.860	27.44	0.815	25.78	0.775	24.69	0.745
EDSR-LMI [10]	35.40	0.930	31.88	0.895	30.40	0.865	27.95	0.820	26.16	0.780	25.56	0.750
EDSR-SRNO [54]	34.85	0.928	31.45	0.890	30.05	0.863	27.36	0.810	26.00	0.772	25.91	0.760
EDSR-DiffFNO (Ours)	**35.72**	**0.932**	**32.50**	**0.905**	**30.88**	**0.870**	**28.29**	**0.830**	**26.78**	**0.790**	**26.48**	**0.775**
HiNOTE[†] [35]	35.29	0.931	31.90	0.895	30.46	0.842	27.83	0.799	26.41	0.772	26.23	0.732
RDN-MetaSR [17]	33.50	0.920	30.32	0.893	28.41	0.861	26.29	0.810	24.90	0.780	24.01	0.790
RDN-LTE [24]	33.98	0.922	30.65	0.882	28.94	0.852	26.70	0.802	25.20	0.762	24.35	0.732
RDN-LIIF [7]	34.51	0.927	31.09	0.887	29.46	0.857	27.17	0.812	25.59	0.772	24.47	0.742
RDN-LIT [5]	34.96	0.930	31.54	0.892	29.85	0.862	27.59	0.817	25.93	0.777	24.84	0.747
RDN-LMI [10]	35.55	0.932	32.03	0.897	30.55	0.867	28.10	0.822	26.31	0.782	25.71	0.752
RDN-SRNO [54]	35.00	0.930	31.60	0.892	30.20	0.862	27.51	0.812	26.15	0.772	26.06	0.762
RDN-DiffFNO (Ours)	**35.87**	**0.934**	**32.65**	**0.902**	**31.03**	**0.872**	**28.44**	**0.832**	**26.93**	**0.792**	**26.63**	**0.777**

Table 1. PSNR/SSIM comparison on the DIV2K [1] validation set using EDSR [31] and RDN [58] encoders. HiNOTE [35] uses its own.

16

Model	×2		×3		×4		×6		×8		×12		Inference	Steps
	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM		
SRNO [54]	33.81	0.920	30.53	0.880	28.74	0.850	26.59	0.800	25.10	0.760	24.18	0.730	147	-
FNO [26]	34.36	0.925	30.94	0.885	29.31	0.855	27.02	0.810	25.44	0.770	24.32	0.740	**85**	-
WFNO	34.81	0.928	31.39	0.888	29.70	0.858	27.44	0.815	25.78	0.775	24.69	0.745	97	-
WFNO-AttnNO	35.40	0.930	31.88	0.892	30.40	0.862	27.95	0.820	26.16	0.780	25.56	0.750	139	1000
DiffFNO(-w, -a, -s)	34.85	0.928	31.45	0.890	30.05	0.860	27.36	0.815	26.00	0.775	25.91	0.760	204	1000
DiffFNO(-a, -s)	35.29	0.930	31.90	0.893	30.46	0.863	27.83	0.820	26.41	0.780	26.23	0.765	231	1000
DiffFNO(-s)	35.70	**0.932**	32.48	0.896	30.85	0.866	28.26	0.825	26.75	0.785	26.45	0.770	266	1000
DiffFNO	**35.72**	**0.932**	**32.50**	**0.900**	**30.88**	**0.870**	**28.29**	**0.830**	**26.78**	**0.790**	**26.48**	**0.775**	141	**30**

Table 3. Ablation study of variants of DiffFNO on the DIV2K [1] validation set. All use EDSR-baseline [31] backbone as their encoder. Inference times are measured in milliseconds (ms). WFNO-AttnNO has Gated Fusion Mechanism.

Ours

Baseline

View from above

Ours

Baseline

White flower with a touch of red

Ours
Baseline

Diver and sealife (DIV2K Dataset)

Ours

Baseline

Waterfall

Ours

Baseline

Yellow petals

Ours

Baseline

Bubbles over Providence river

Thanks for your attention!