Implicit neural representation

17-12-2024

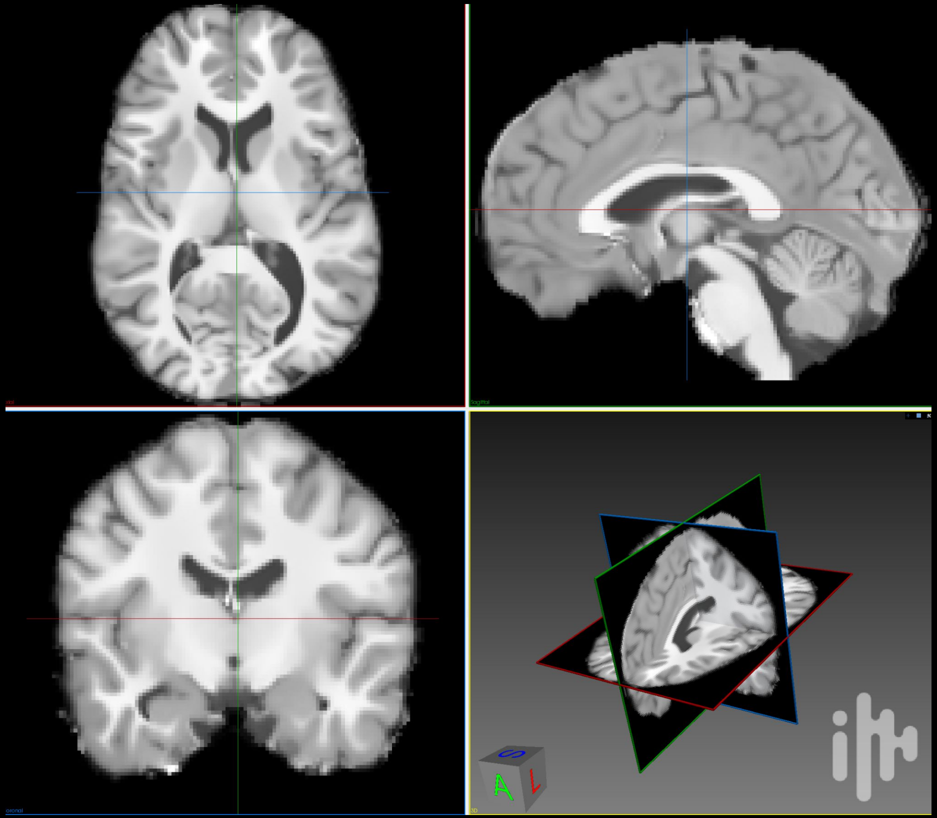
References

MICCAI 2024 Tutorial on Implicit Neural Representations for Medical Imaging

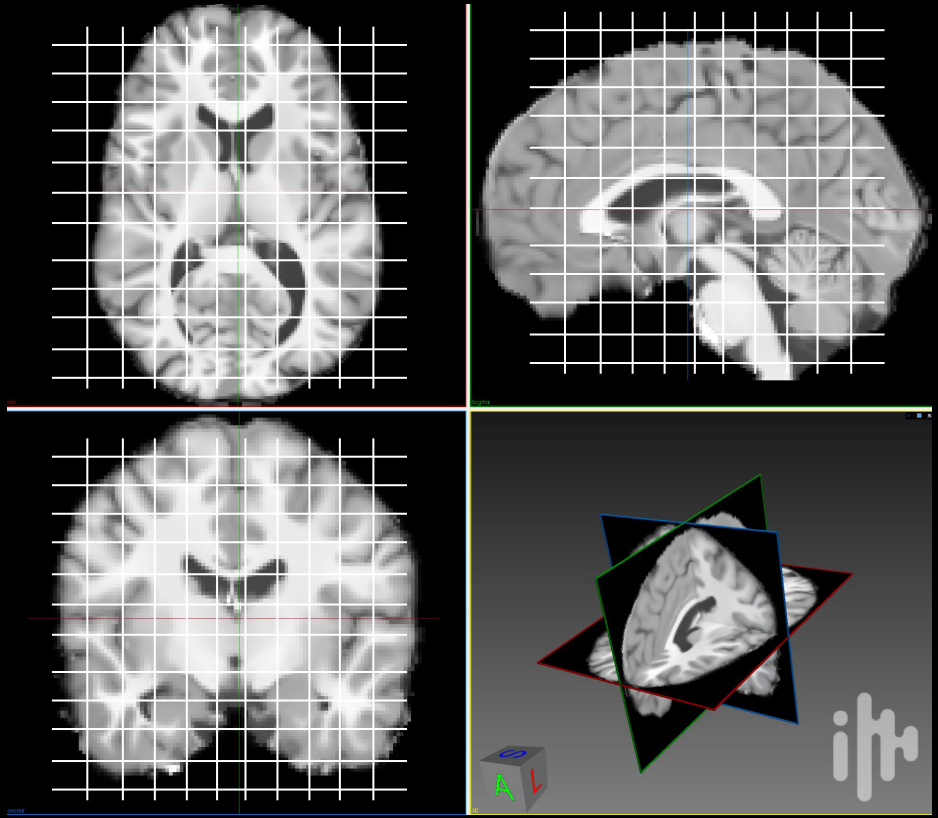
https://inr4miccai.github.io/

SIREN on Github

https://github.com/vsitzmann/siren



$$f : \mathbb{Z}_{0+}^{N} \rightarrow \mathbb{R}$$



$$f : \mathbb{Z}_{0+}^{N} \to \mathbb{R}$$

$$f : ? \to \mathbb{R}$$

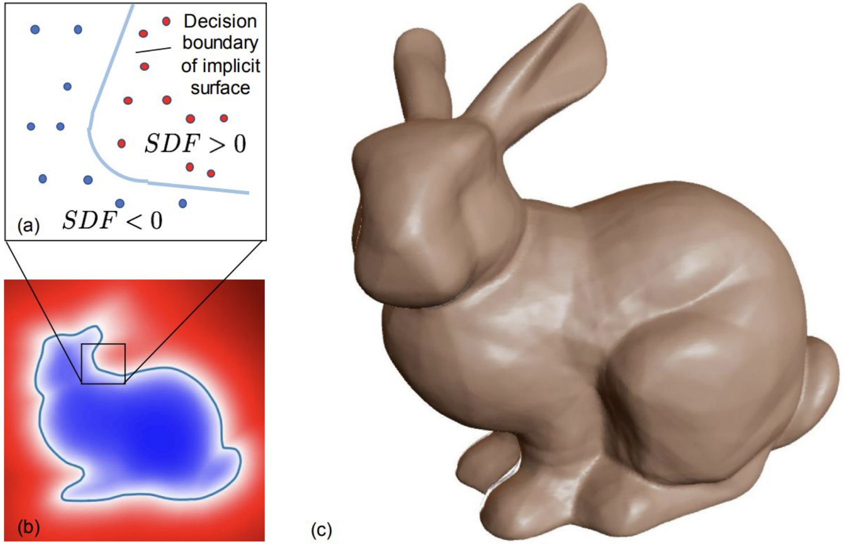
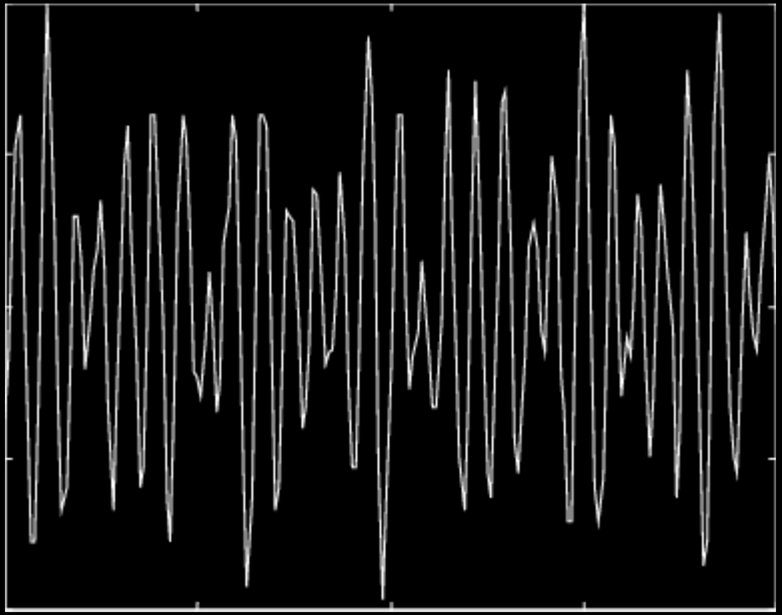


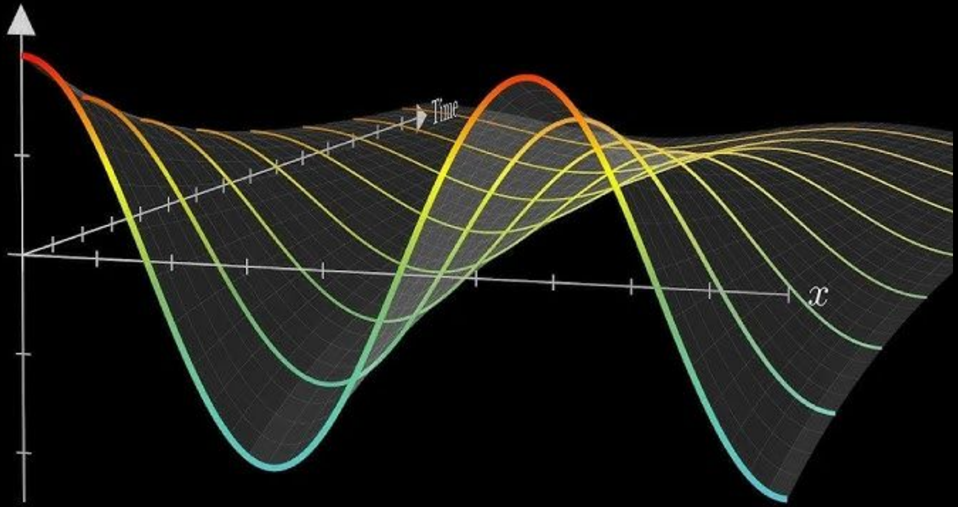
Figure 2: Our DeepSDF representation applied to the Stanford Bunny: (a) depiction of the underlying implicit surface $SDF = 0$ trained on sampled points inside $SDF < 0$ and outside $SDF > 0$ the surface, (b) 2D cross-section of the signed distance field, (c) rendered 3D surface recovered from $SDF = 0$. Note that (b) and (c) are recovered via DeepSDF.

$$f : \mathbb{R}^N \to \mathbb{R}$$

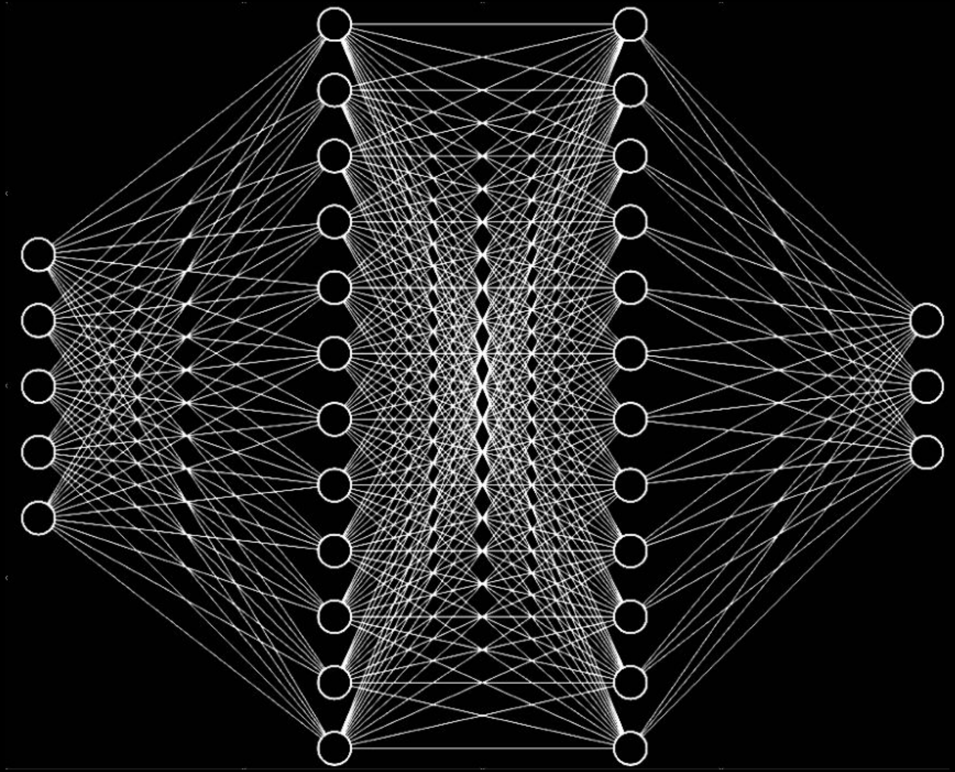
Park, Jeong Joon, et al. "Deepsdf: Learning continuous signed distance functions for shape representation." Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2019.



$$f : \mathbb{R} \to \mathbb{R}$$



$$F : \mathbb{R}^{N^2} \times \mathbb{R}^{N} \times \mathbb{R} \times U \to \mathbb{R}$$



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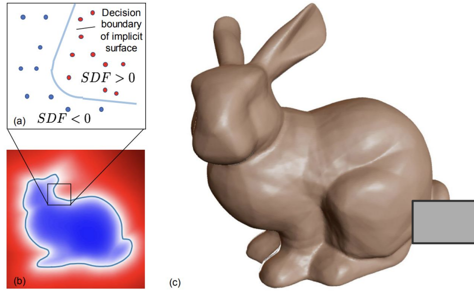

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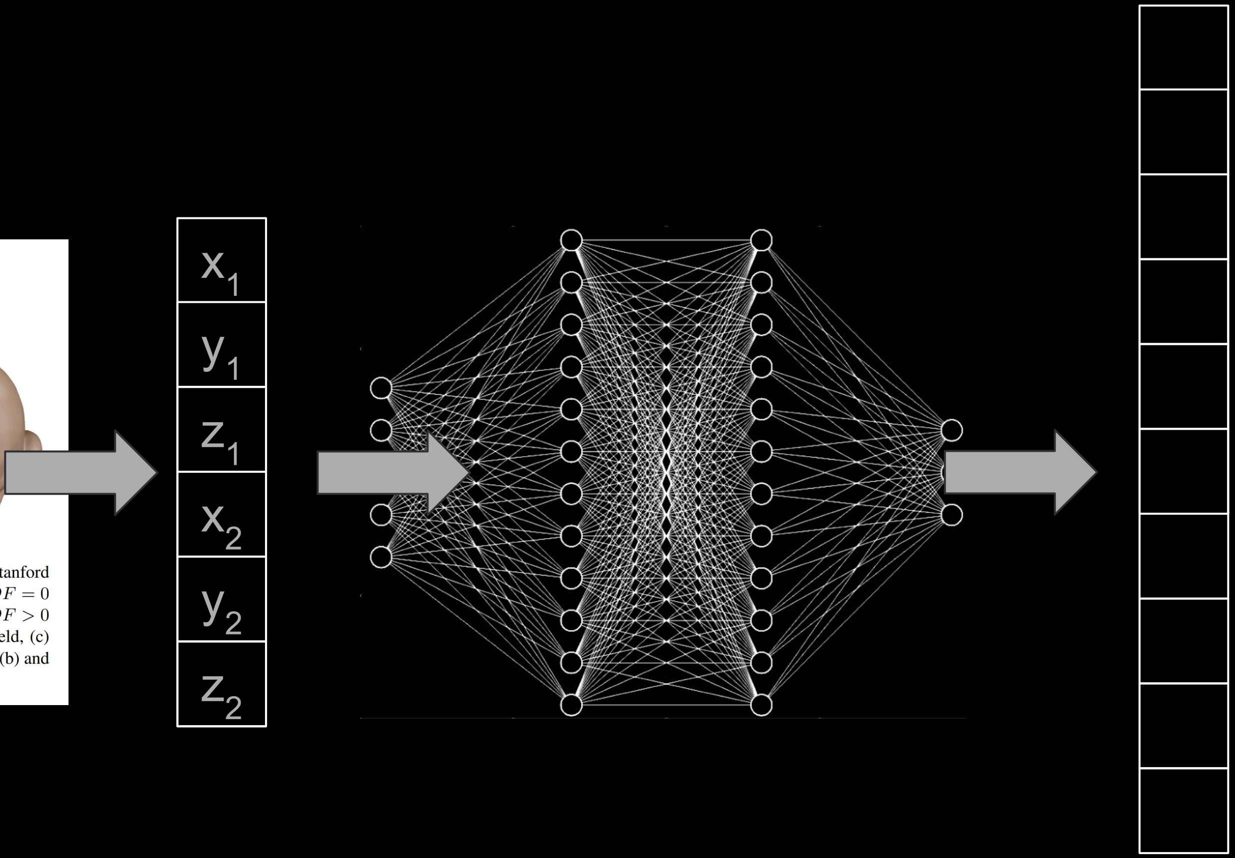
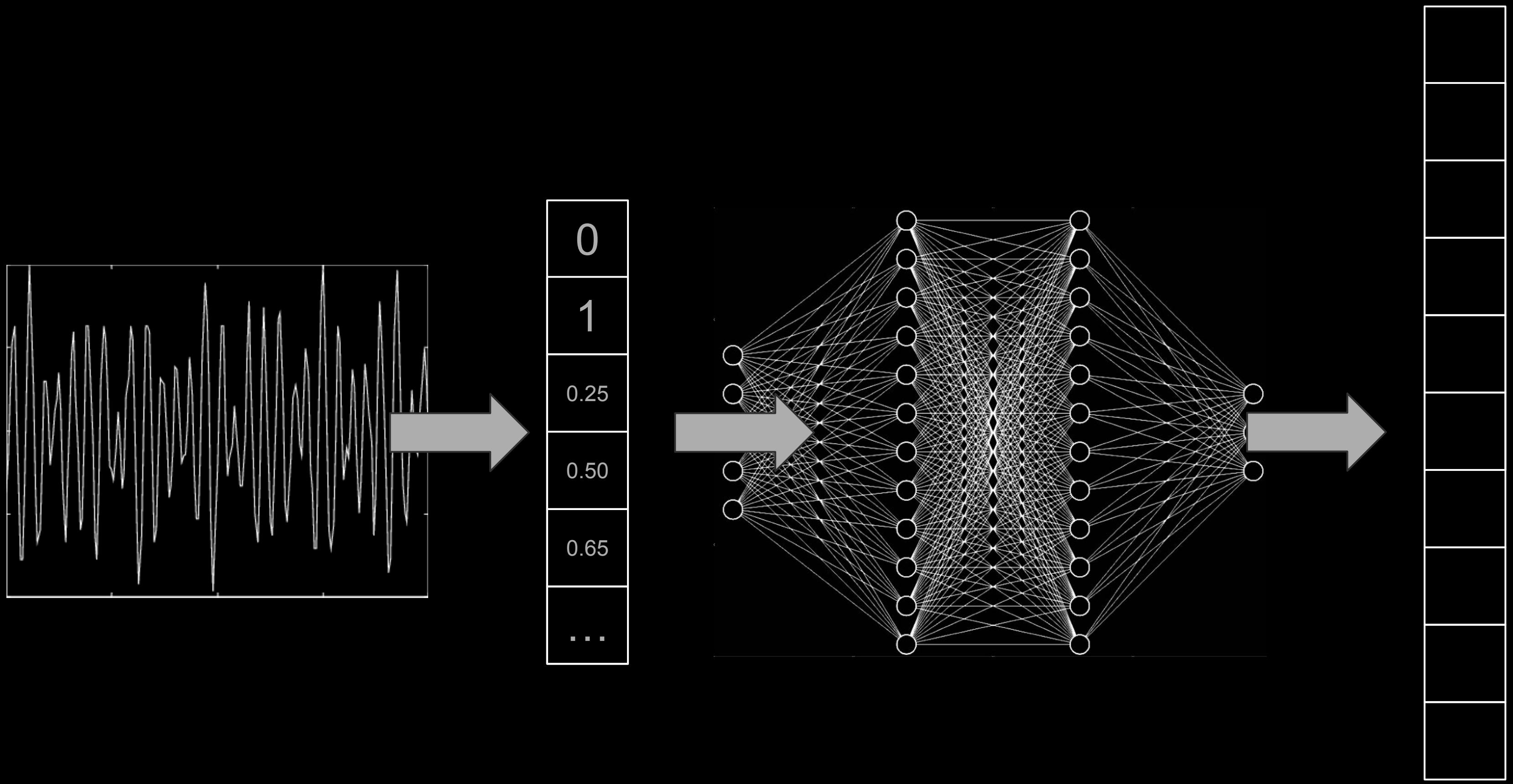
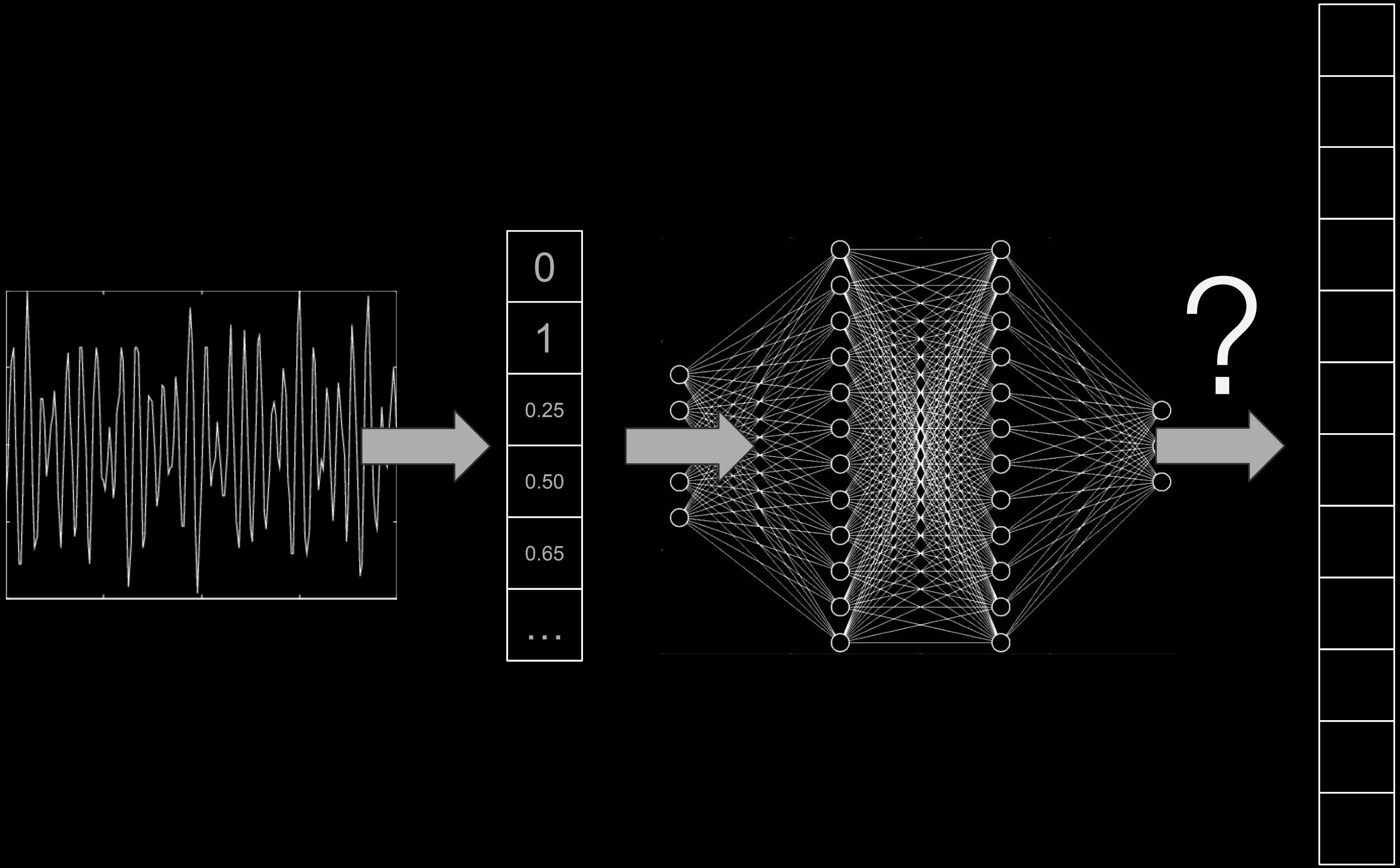
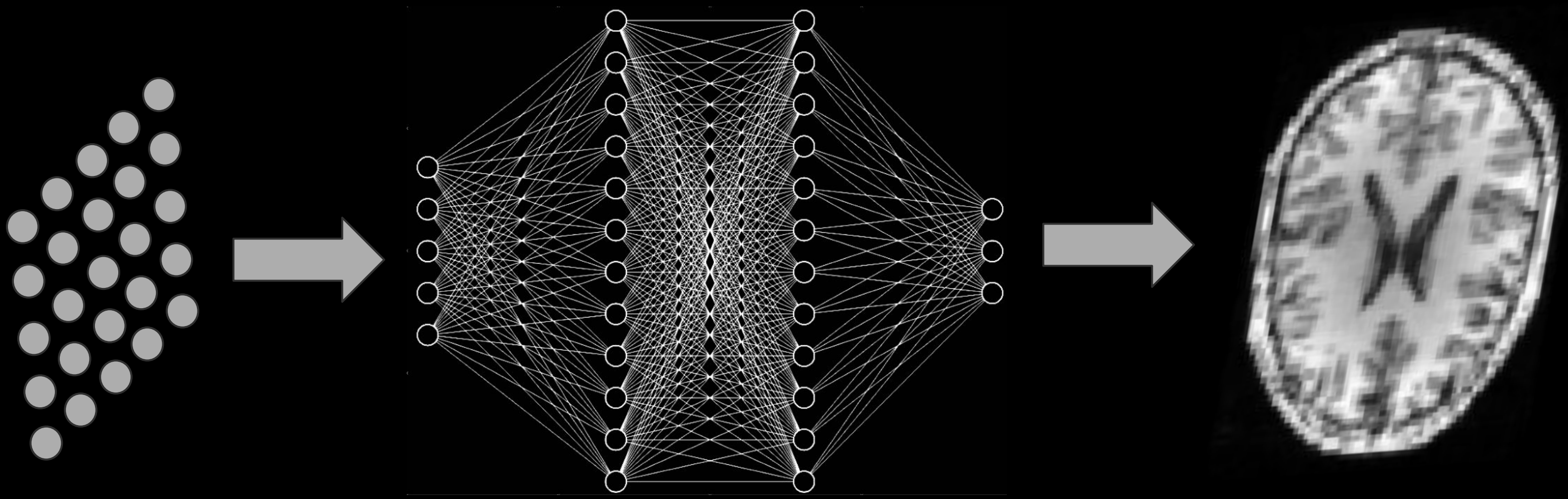


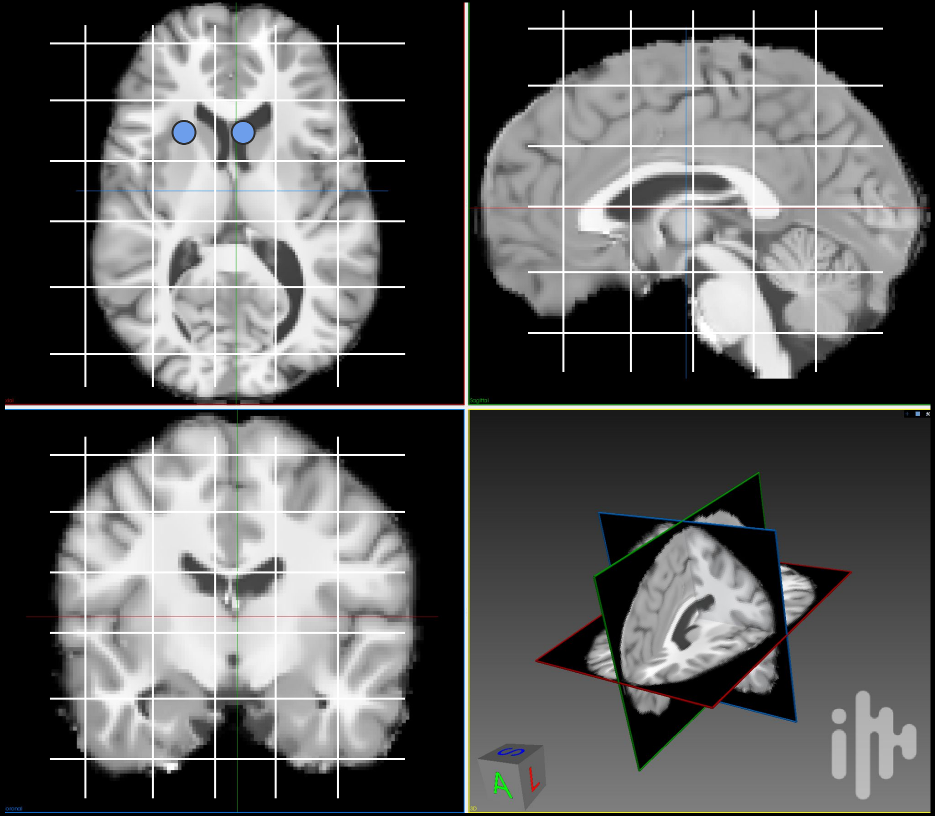

0
1
0.25
0.50
0.65
...


0
1
0.25
0.50
0.65
...
?

$$f_\theta(x) : \mathbb{R}^N \rightarrow \mathbb{R}^M$$

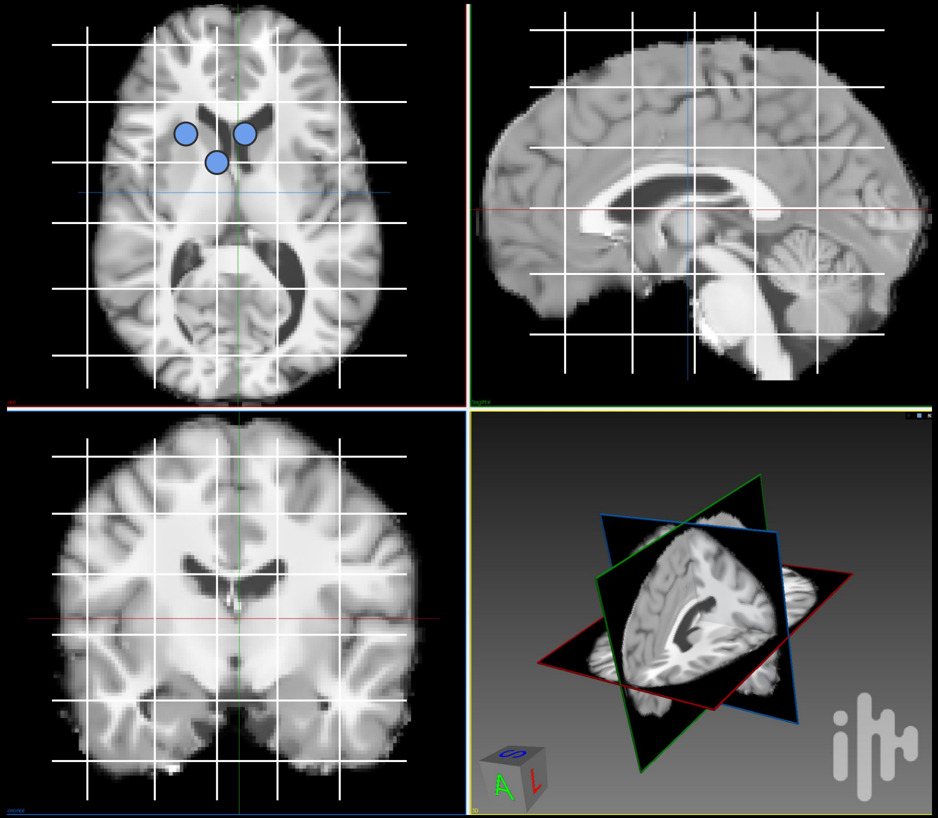
"a field is a physical quantity, represented by a scalar, vector, or tensor, that has a value for each point in space and time." - Wikipedia, field (physics)





Training

$$f_\theta(x) : \mathbb{R}^3 \rightarrow \mathbb{R}$$



"Testing"

$$f_\theta(x) : \mathbb{R}^3 \to \mathbb{R}$$

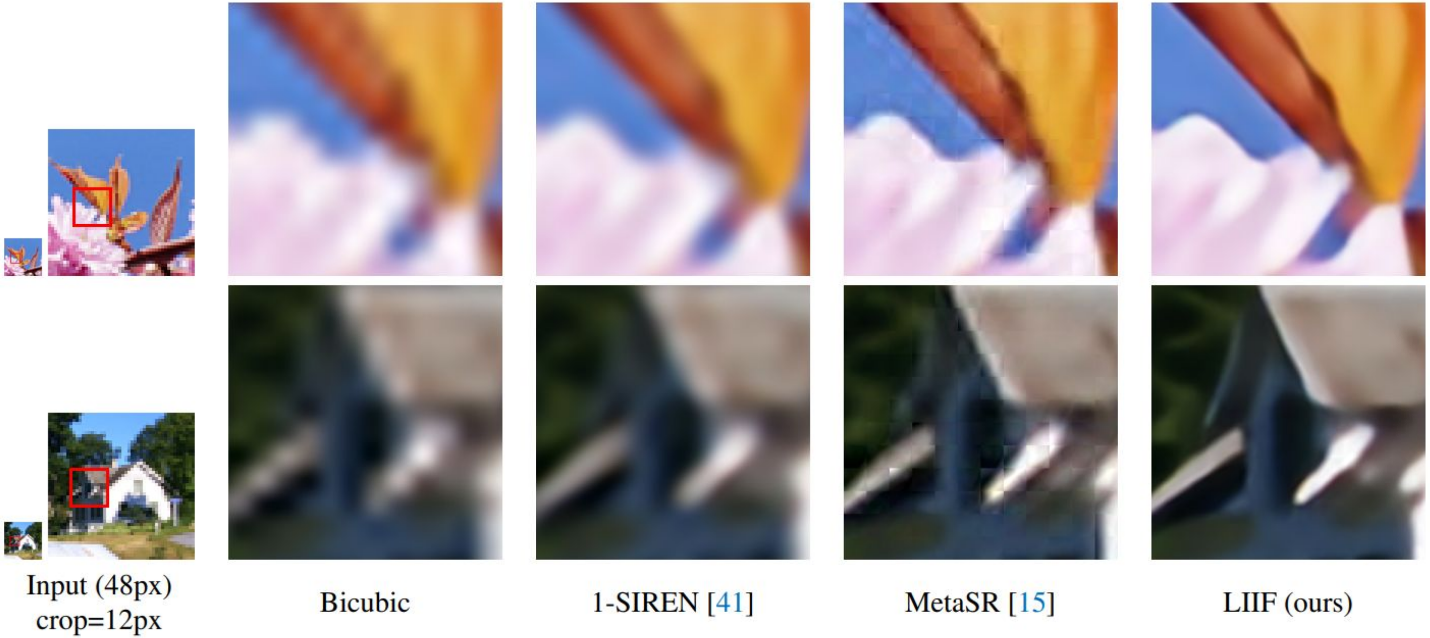


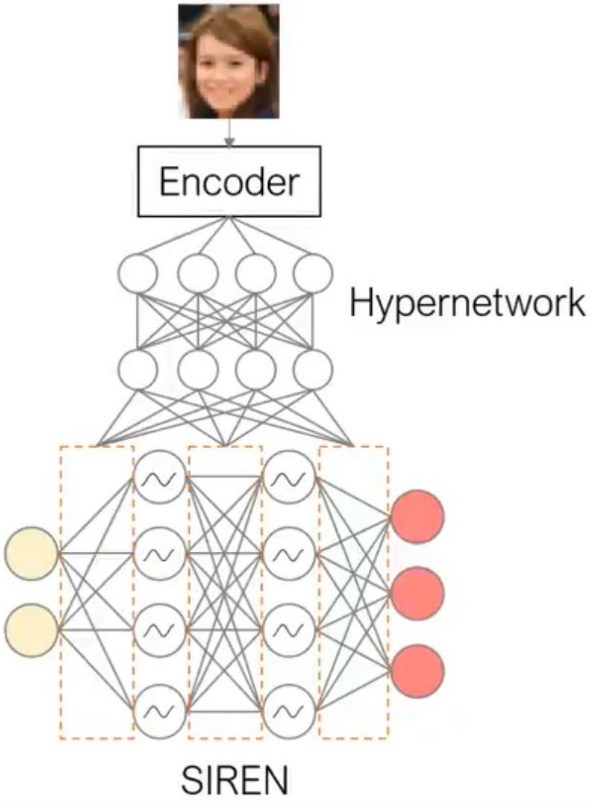
Figure 5: **Qualitative comparison of learning continuous representation.** The input is a 48×48 patch from images in DIV2K validation set, a red box indicates the crop area for demonstration ($\times 30$). 1-SIREN refers to fitting an independent implicit function for the input image. MetaSR and LIIF are trained for continuous random scales in $\times 1$–$\times 4$ and tested for $\times 30$ for evaluating the generalization to arbitrary high precision of the continuous representation.

Chen, Yinbo, Sifei Liu, and Xiaolong Wang. "Learning continuous image representation with local implicit image function." Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2021.

In practice (see notebook)

Limited to a single function ..?

Limited to a single function ..? Yes



https://x.com/vincesitzmann/status/127412150
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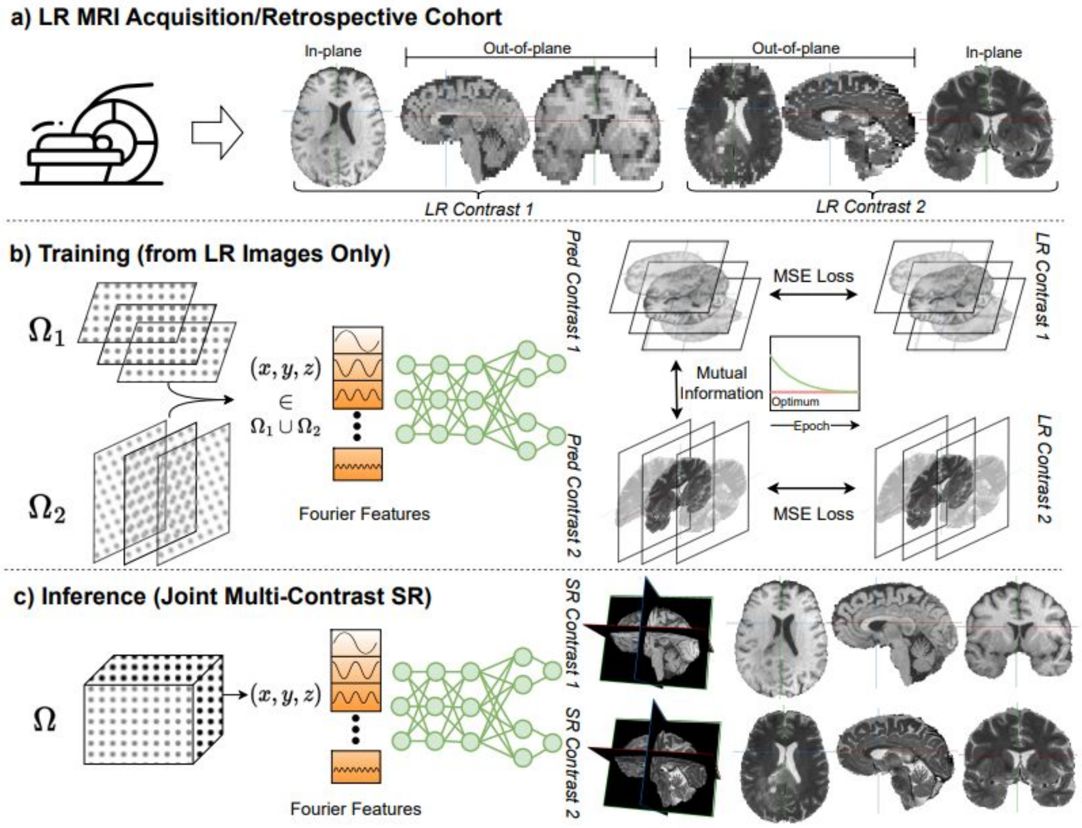
What else ?



McGinnis, Julian, et al. "Single-subject multi-contrast MRI super-resolution via implicit neural representations." International Conference on Medical Image Computing and Computer-Assisted Intervention. Cham: Springer Nature Switzerland, 2023.

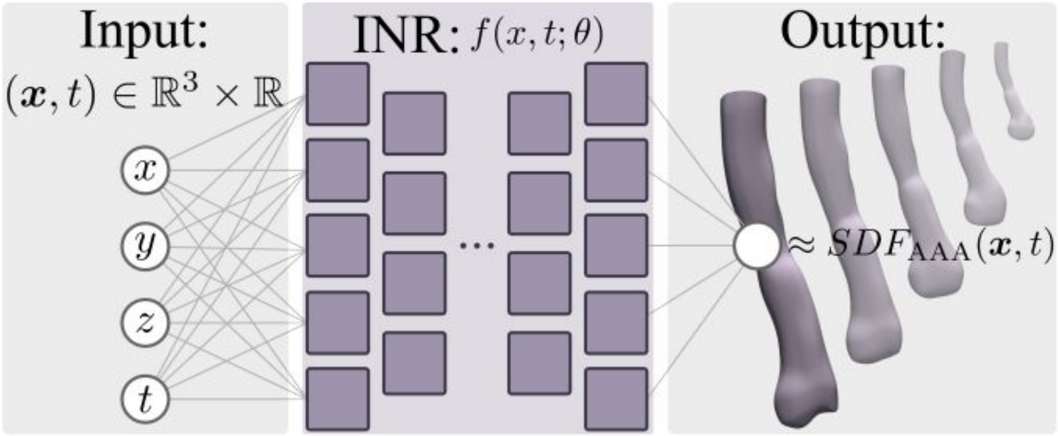


Fig. 1. Schematic representation of our INR, taking spatiotemporal coordinates $(\boldsymbol{x}, t)$ as an input, outputting $SDF(\boldsymbol{x}, t)$ of the AAA surface. Note that a single INR represents the complete evolving AAA of a patient.

Alblas, D., Hofman, M., Brune, C., Yeung, K. K., & Wolterink, J. M. (2023, June). Implicit neural representations for modeling of abdominal aortic aneurysm progression. In International Conference on Functional Imaging and Modeling of the Heart (pp. 356-365). Cham: Springer Nature Switzerland.

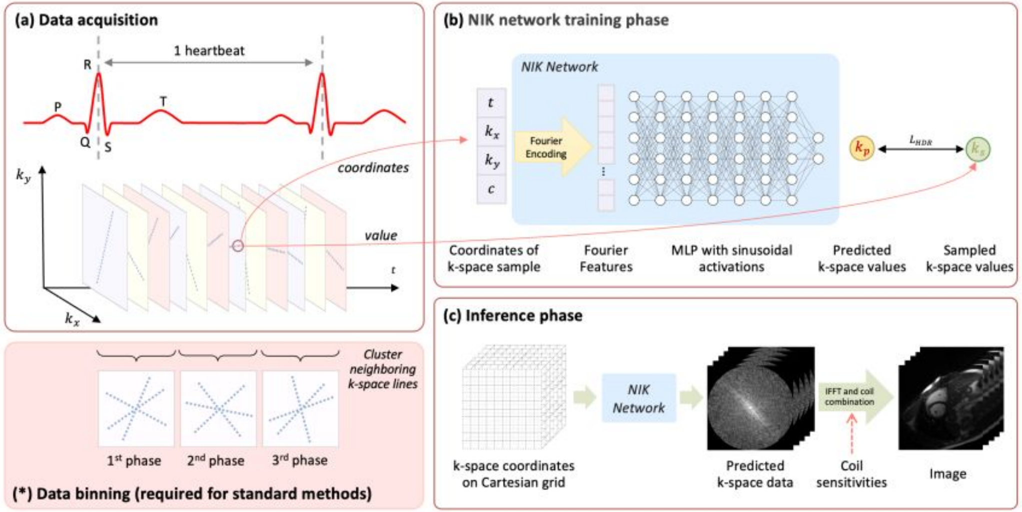
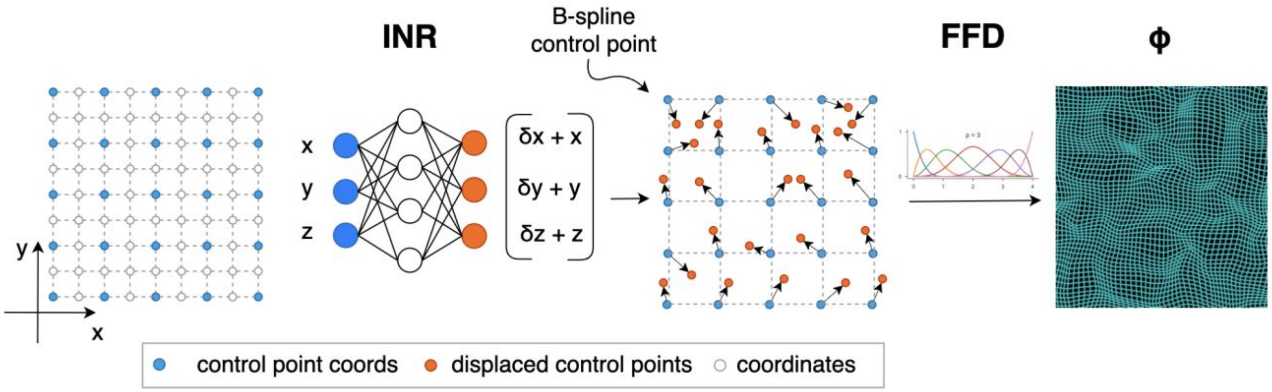


Fig. 1. Schematic illustration of neural implicit k-space (NIK). (a) The k-space lines (spokes) are sorted and mapped to one heartbeat. Instead of the traditional data binning (*), we train the MLP to learn the implicit representation of the k-space with the k-space coordinate-intensity pairs (b). t, k_x, k_y, and c refer to time point, k-space coordinates, and coil channel, respectively. (c) In the inference phase, we feed a set of coordinates from the Cartesian grid and obtain the corresponding k-space signal value. The final image can be easily reconstructed by applying the inverse fast Fourier transform and coil combination.

Huang, Wenqi, et al. "Neural implicit k-space for binning-free non-cartesian cardiac MR imaging." International Conference on Information Processing in Medical Imaging. Cham: Springer Nature Switzerland, 2023.



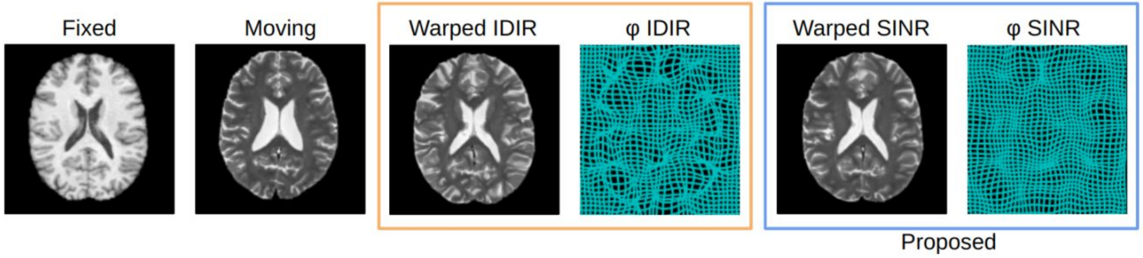


Figure 2: Qualitative results on T1w-T2w registration. The proposed SINR with SIREN activations achieves more plausible results (0.51% folding ratio) compared to IDIR with SIREN (Wolterink et al., 2022) activation (0.87% folding ratio).

Sideri-Lampretsa, V., McGinnis, J., Qiu, H., Paschali, M., Simson, W., & Rueckert, D. (2024). SINR: Spline-enhanced implicit neural representation for multi-modal registration. In *Medical Imaging with Deep Learning*.

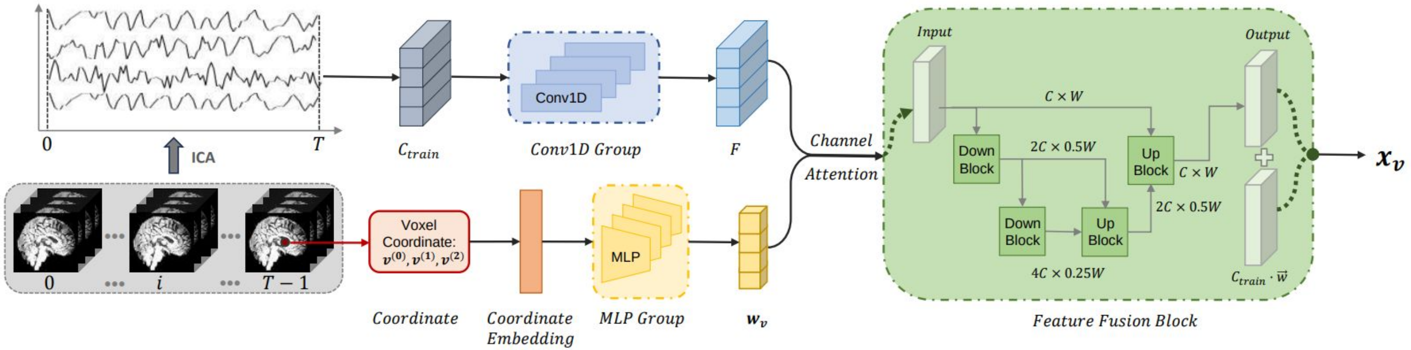


Fig. 2: The workflow and the basic structure of the proposed compression approach.

Table 1: The performance of different compressors at a specific compression ratio, roughly 100×.Methods marked in red and with the * suffix are the best performing methods, while those marked in blue and with the # suffix are the second best performing methods.

Method	ICAINR(ours)	H.264	H.265	JPEG	NeRF	HNeRV	SIREN	SSF	DVC
Compression Ratio↑	127.83×*	97.49×	125.99×#	102.95×	99.77×	102.71×	99.76×	66.99×	81.13×
PSNR(dB)↑	79.31*	65.37	61.49	56.14	67.63	70.49#	69.09	33.03	57.09
1 - SSIM↓	5.54E-5*	1.96E-3	8.38E-4	2.74E-3	4.83E-4	2.62E-3	4.01E-4#	9.39E-2	4.39E-4
Mean of FLA Residual↓	0.32*	1.15	1.04	1.19	0.37#	0.86	1.10	1.21	1.32
Std of FLA Residual↓	0.24*	0.60	0.58	0.72	0.34#	0.57	0.50	0.61	0.55
Mean of FCA Residual↓	0.09*	0.32	0.37	0.33	0.18	0.29	0.12#	0.50	0.29
Std of FCA Residual↓	0.04*	0.22	0.28	0.14	0.12	0.22	0.08#	0.35	0.24

Li, Ruoran, et al. "A Compact Implicit Neural Representation for Efficient Storage of Massive 4D Functional Magnetic Resonance Imaging." arXiv preprint arXiv:2312.00082 (2023).

Gaining popularity ?

implicit

- **TrIND: Representing Anatomical Trees by Denoising Diffusion of Implicit Neural Fields**
  Sinha, Ashish; Hamarneh, Ghassan
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[illegible]
  [PDF][Paper Information and Reviews][BibTex]

- **Self-Supervised k-Space Regularization for Motion-Resolved Abdominal MRI Using Neural Implicit k-Space Representations**
  Spieker, Veronika; Eichhorn, Hannah; Stelter, Jonathan K.; Huang, Wenqi; Braren, Rickmer F.; Rueckert, Daniel; Sahli Costabal, Francisco; Hammernik, Kerstin; Prieto, Claudia; Karampinos, Dimitrios C.; Schnabel, Julia A.
  [PDF][Paper Information and Reviews][BibTex]

- **Reference-free Axial Super-resolution of 3D Microscopy Images using Implicit Neural Representation with a 2D Diffusion Prior**
  Lee, Kyungryun; Jeong, Won-Ki
  [PDF][Paper Information and Reviews][BibTex]

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  Xu, Yanyu; Xia, Yingzhi; Fu, Huazhu; Goh, Rick Siow Mong; Liu, Yong; Xu, Xinxing
  [PDF][Paper Information and Reviews][BibTex]

- **Implicit Representation Embraces Challenging Attributes of Pulmonary Airway Tree Structures**
  Zhang, Minghui; Zhang, Hanxiao; You, Xin; Yang, Guang-Zhong; Gu, Yun
  [PDF][Paper Information and Reviews][BibTex]

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  Al-Haj Hemidi, Ziad; Weihsbach, Christian; Heinrich, Mattias P.
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  [PDF][Paper Information and Reviews][BibTex]

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  Yang, Jiancheng; Sedykh, Ekaterina; Adhinarta, Jason Ken; Le, Hieu; Fua, Pascal
  [PDF][Paper Information and Reviews][BibTex]

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  Tan, Junpeng; Zhang, Xin; Qing, Chunmei; Yang, Chaoxiang; Zhang, He; Li, Gang; Xu, Xiangmin
  [PDF][Paper Information and Reviews][BibTex]

neural field

- **Zero-shot Low-field MRI Enhancement via Denoising Diffusion Driven Neural Representation**
  Lin, Xiyue; Du, Chenhe; Wu, Qing; Tian, Xuanyu; Yu, Jingyi; Zhang, Yuyao; Wei, Hongjiang
  [PDF][Paper Information and Reviews][BibTex]

- **Vestibular schwannoma growth prediction from longitudinal MRI by time-conditioned neural fields**
  Chen, Yunjie; Wolterink, Jelmer M.; Neve, Olaf M.; Romeijn, Stephan R.; Verbist, Berit M.; Hensen, Erik F.; Tao, Qian; Staring, Marius
  [PDF][Paper Information and Reviews][BibTex]

- **TrIND: Representing Anatomical Trees by Denoising Diffusion of Implicit Neural Fields**
  Sinha, Ashish; Hamarneh, Ghassan
  [PDF][Paper Information and Reviews][BibTex]

- **Spatio-temporal neural distance fields for conditional generative modeling of the heart**
  Sørensen, Kristine; Diez, Paula; Margeta, Jan; El Youssef, Yasmin; Pham, Michael; Pedersen, Jonas Jalili; Kühl, Tobias; de Backer, Ole; Kofoed, Klaus; Camara, Oscar; Paulsen, Rasmus
  [PDF][Paper Information and Reviews][BibTex]

- **RoCoSDF: Row-Column Scanned Neural Signed Distance Fields for Freehand 3D Ultrasound Imaging Shape Reconstruction**
  Chen, Hongbo; Gao, Yuchong; Zhang, Shuhang; Wu, Jiangjie; Ma, Yuexin; Zheng, Rui
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- **Generating Anatomically Accurate Heart Structures via Neural Implicit Fields**
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  [PDF][Paper Information and Reviews][BibTex]

- **Estimating Neural Orientation Distribution Fields on High Resolution Diffusion MRI Scans**
  [illegible]
  [PDF][Paper Information and Reviews][BibTex]

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  Li, Wenda; Hayashi, Yuichiro; Oda, Masahiro; Kitasaka, Takayuki; Misawa, Kazunari; Mori, Kensaku
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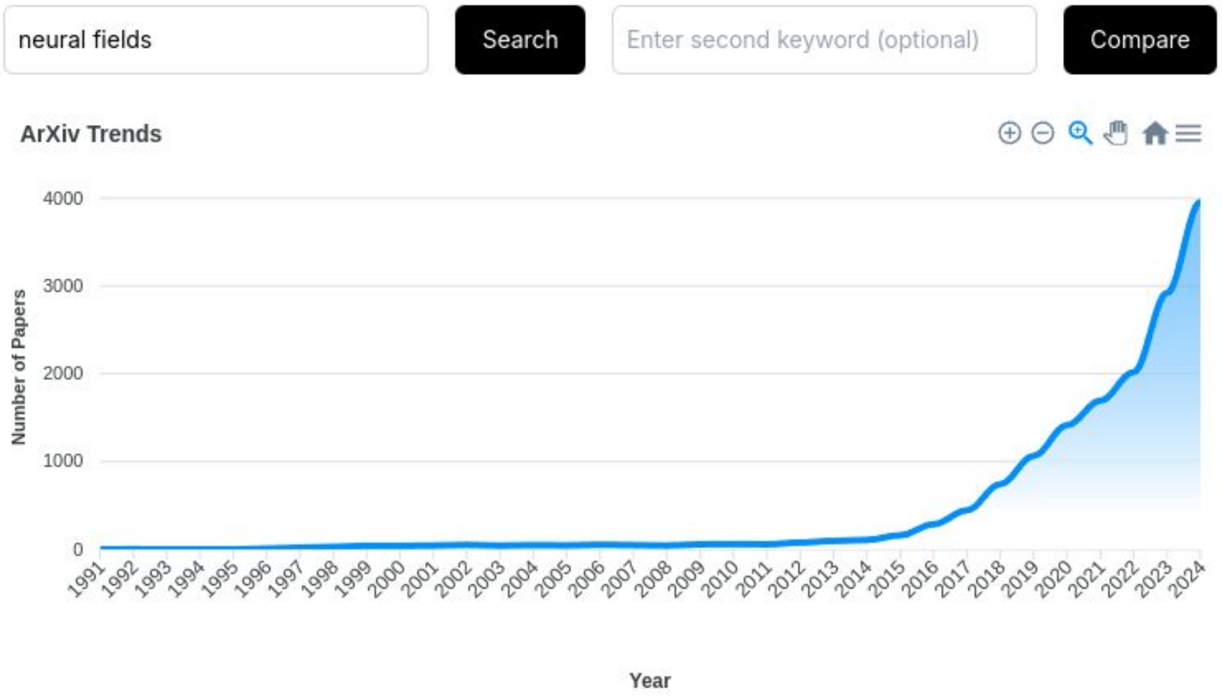

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