SISMIK: Search In Segmented Motion Input (in) K-space

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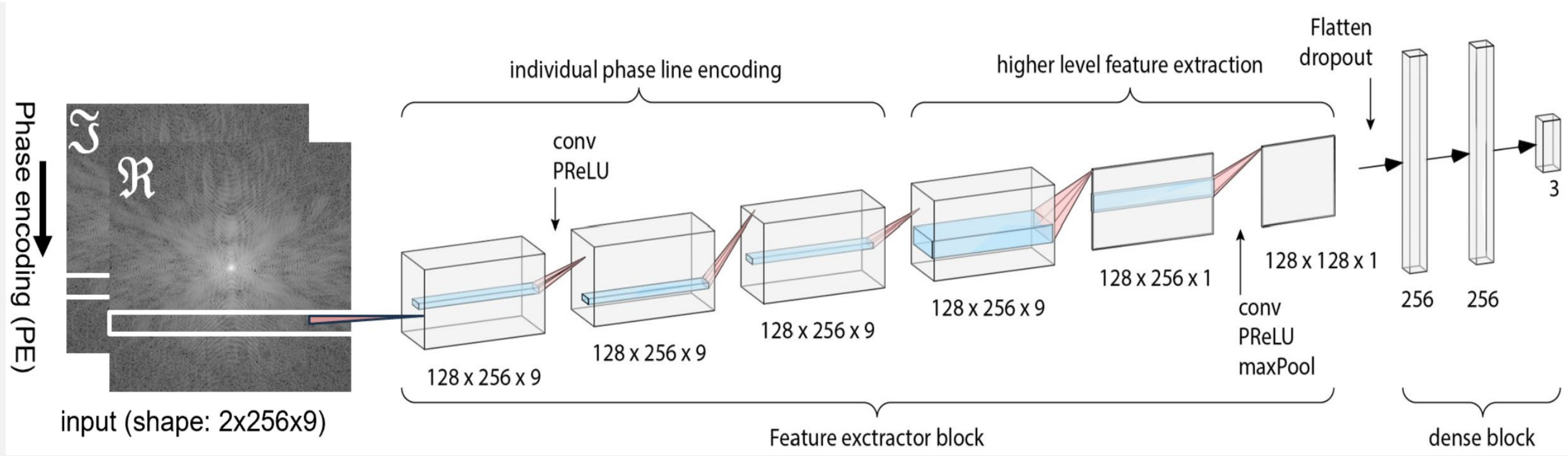
BACKGROUND & AIMS

MRI is **highly sensitive to patient motion** because its inherently sequential acquisition process requires long scan times. Unlike conventional X-ray, MRI does not directly produce an image. Instead, it records magnetic resonance signals in a **frequency domain** known as **"k-space."** The final image used by radiologists is obtained through a "reconstruction" process using the **Fourier transform**.

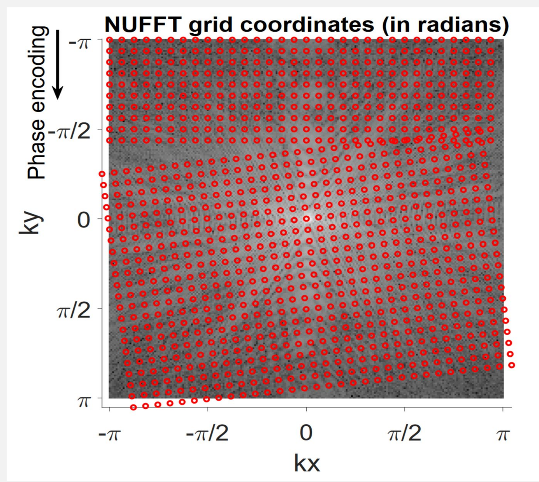
We propose SISMIK [1], a **retrospective motion correction system** for k-space data that reconstructs images with fewer motion artifacts. The system is hybrid, **combining artificial intelligence with traditional algorithms** to leverage the strengths of both approaches.

First **prototype** trained and tested on 2D **T1w classical Spin-Echo** brain acquisitions is being **extended** to 2D **T2w turbo-Spin-Echo** which is very widely used in the clinical setting.

METHODS



▲**Figure 1.** Deep convolutional neural network to estimate head motion trajectory in k-space. The input is a narrow region of k-space. Multiple instances of SISMIK trained for each spatial frequency band.

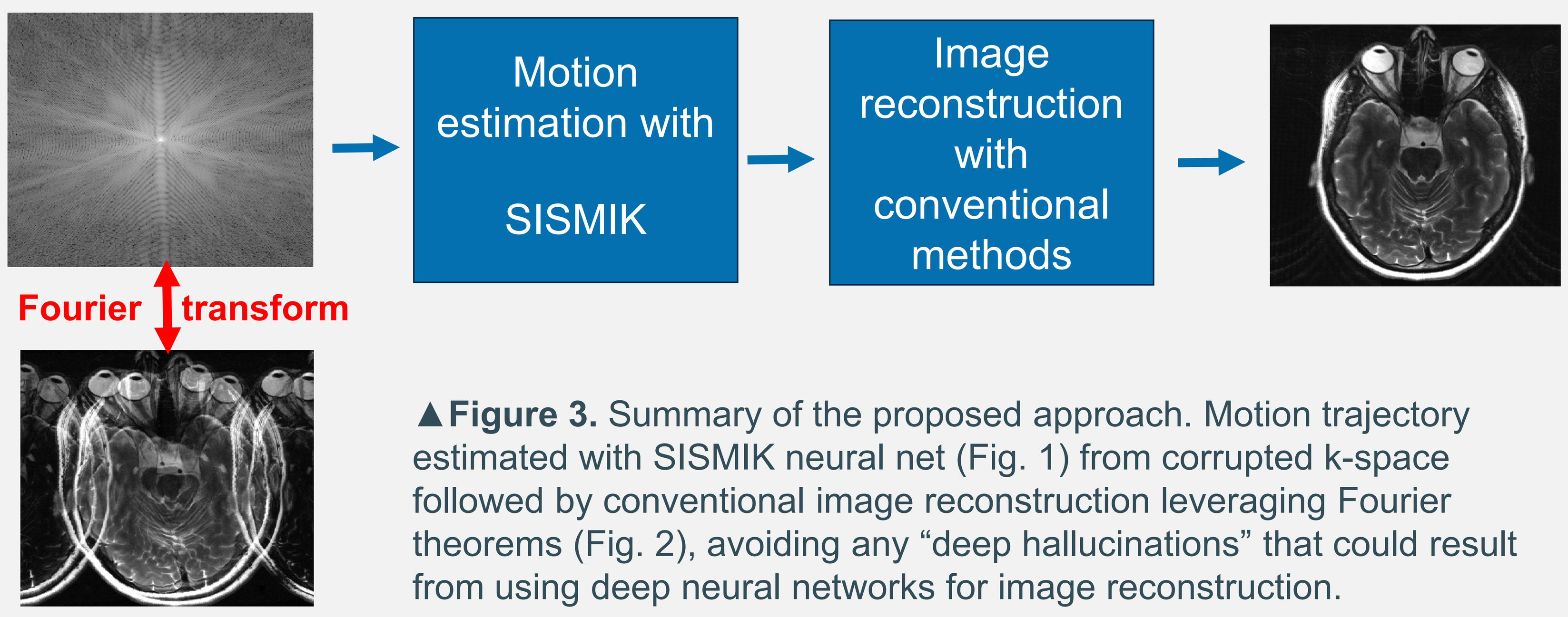


$$\Phi = e^{-i2\pi \boldsymbol{k}_x \odot \boldsymbol{t}_x} e^{-i2\pi \boldsymbol{k}_y^\top \odot \boldsymbol{t}_y^\top}$$

$$\widetilde{\boldsymbol{Y}} = \boldsymbol{Y} \odot \Phi$$

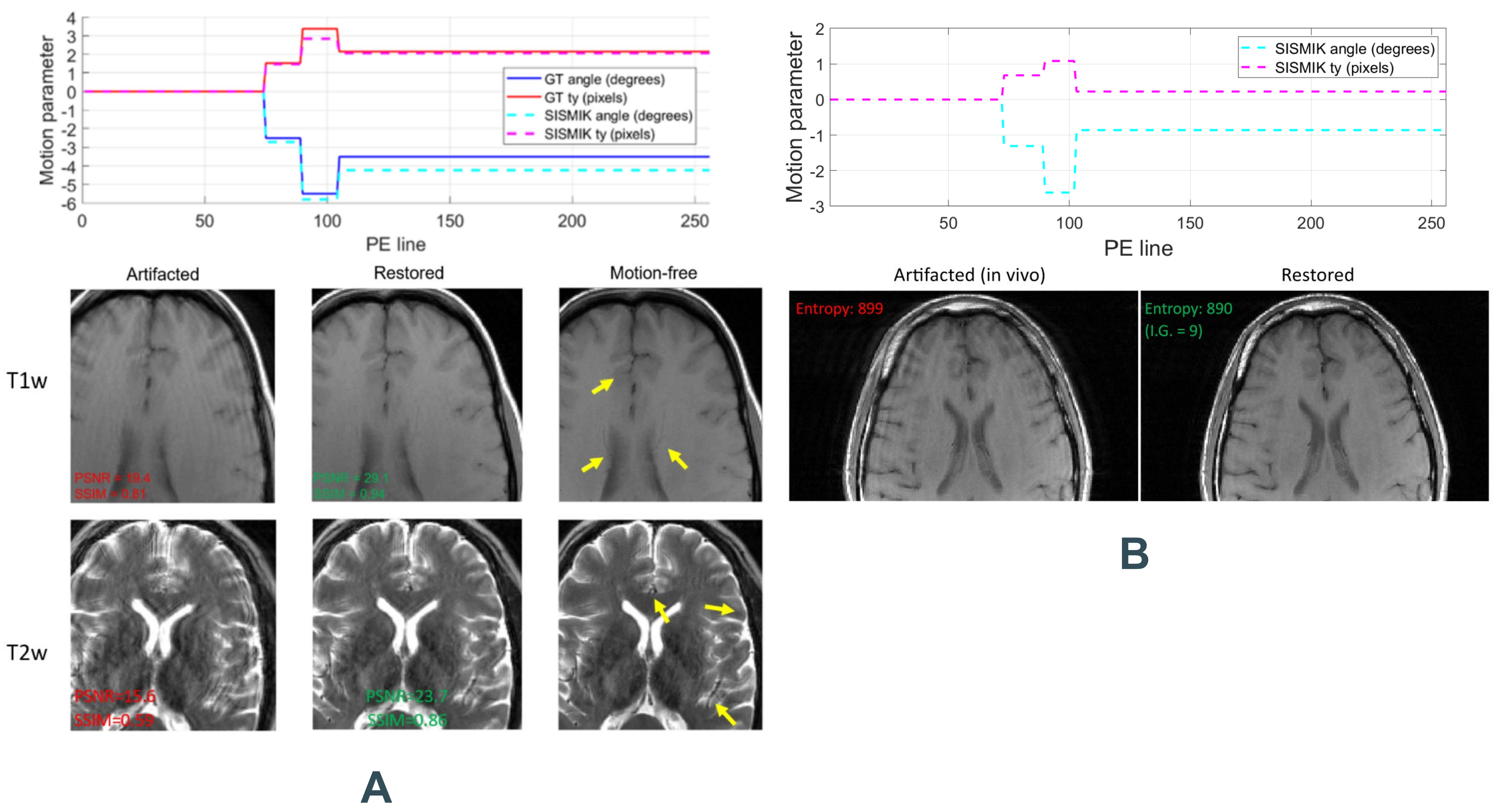
$$\widehat{\boldsymbol{x}}_{\mathrm{LSQR}} = \mathrm{argmin}_{\boldsymbol{x}} ||\boldsymbol{F}_{\mathrm{NUFFT}}\boldsymbol{x} - \mathrm{vec}(\widetilde{\boldsymbol{Y}})||_2^2$$

▲**Figure 2.** Motion correction using trajectory estimated by SISMIK (Fig. 1) and leveraging Fourier theorems to ''undo'' the effects of translation and rotation (in-plane rigid-body motion). A motion trajectory with a single event is shown in red.

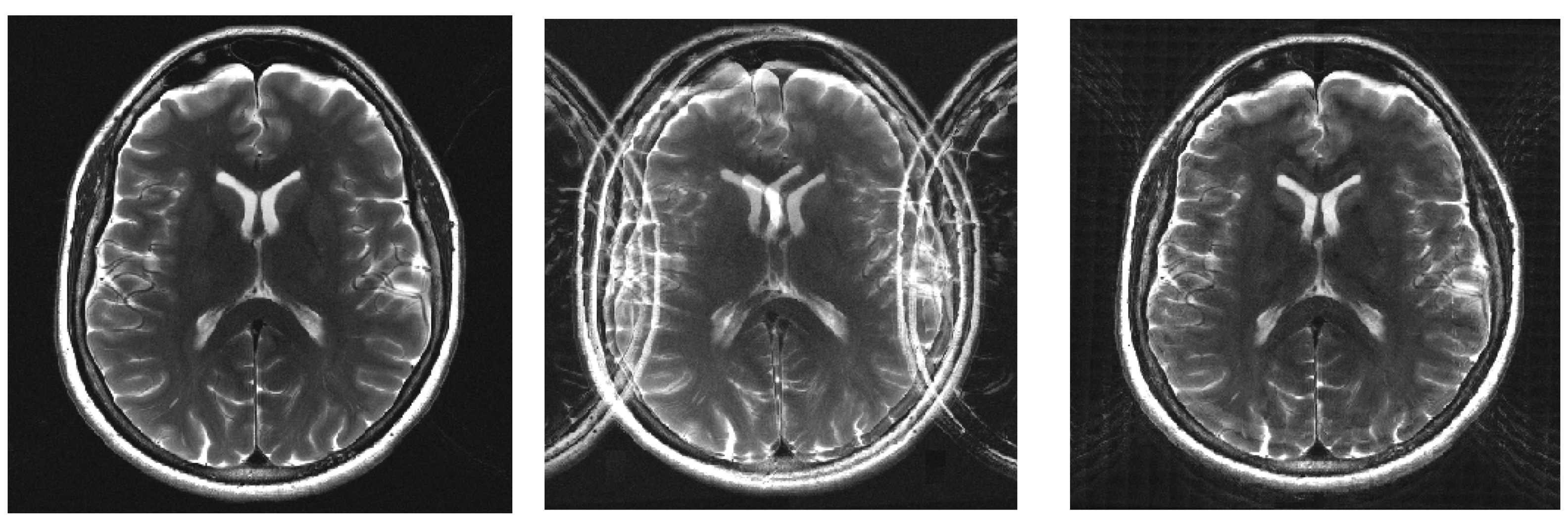


▲**Figure 3.** Summary of the proposed approach. Motion trajectory estimated with SISMIK neural net (Fig. 1) from corrupted k-space followed by conventional image reconstruction leveraging Fourier theorems (Fig. 2), avoiding any "deep hallucinations" that could result from using deep neural networks for image reconstruction.

RESULTS



▲**Figure 4.** (A) Simulated motion trajectory and corresponding reconstruction from SISMIK estimations for two different contrasts highlighting the robustness of SISMIK to contrast variations (model trained only on one type of contrast). (B) In vivo motion estimation and reconstruction from SISMIK estimations.



(A) Source image **(B) Simulated motion** **(C) recon. from known motion parameters**

▲**Figure 5.** 2D Turbo Spin-Echo (TSE) motion simulation of a single motion even of 3.5 degrees in the middle of the acquisition. Due to the TSE k-space acquisition pattern, artifacts exhibit "aliasing-like" effects and blurring. (A) Source motion-free scan, (B) Motion simulation applied to (A), (C) restored from known simulation parameters (residual artifacts remain visible).

CONCLUSION

- Deep neural network prototype trained on 600k+ simulations capable of estimating motion trajectories in k-space **without any motion-free reference** and in a **relative manner**.
- Robust to **changes in contrasts** (thanks to working in k-space) and **"hallucination-free"** (conventional methods for image reconstruction.
- Currently being extended for retrospective motion correction of **Turbo Spin-Echo acquisitions** which are very common in the clinical setting.
- Neural net architecture and simulation procedure need to be adapted to cope with the different acquisition pattern in k-space.
- Long-term goal: integrate SISMIK in the **clinical pipeline** such that radiologists can benefit directly from motion-corrected images for improved diagnosis.

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References: [1] O. Dabrowski et al., 2024, *IEEE Transactions on Medical Imaging, doi: 10.1109/TMI.2024.3446450.*.

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