EFFECT OF TRAJECTORY ON IMAGING

BY: ZAJIBA SADIA ISLAM

501279357

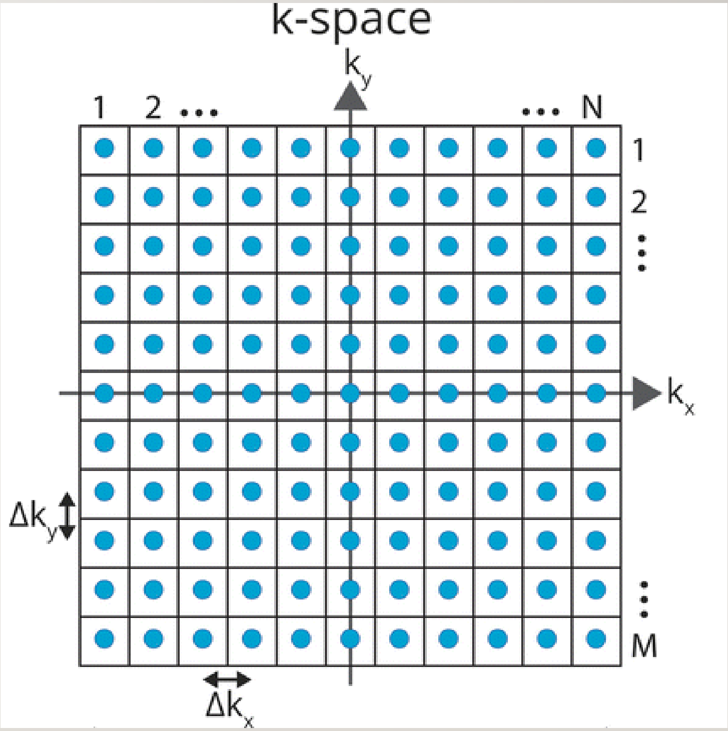
INTRODUCTION TO MRI TRAJECTORIES

PATH THAT K-SPACE SAMPLING FOLLOWS DURING THE IMAGING PROCESS.

SIGNIFICANTLY IMPACT IMAGE QUALITY, ACQUISITION TIME, AND ARTIFACTS

UNDERSTANDING K-SPACE

- Data acquisition space in MRI where spatial frequency information is stored.
- Typically represented as a 2D grid. The center of k-space contains low spatial frequencies, while the periphery contains high spatial frequencies.
- Data points in k-space correspond to different spatial frequencies of the image.
- Each point in k-space contains complex numbers representing both the amplitude and phase of the signal.
- The trajectory determines how this space is sampled.



TYPES OF TRAJECTORIES IN MRI

- **Cartesian Trajectories:** Standard rectilinear sampling.
- **Radial Trajectories:** Spokes radiating from the center.
- **Spiral Trajectories:** Continuous spiral from the center outward.
- **Echo-planar imaging (EPI):** Zig-zag pattern sampling.
- **Non-Cartesian Trajectories:** Any non-linear path (e.g., PROPELLER, Lissajous).

UNDERLYING PHYSICS OF MRI TRAJECTORIES

Gradient Fields:

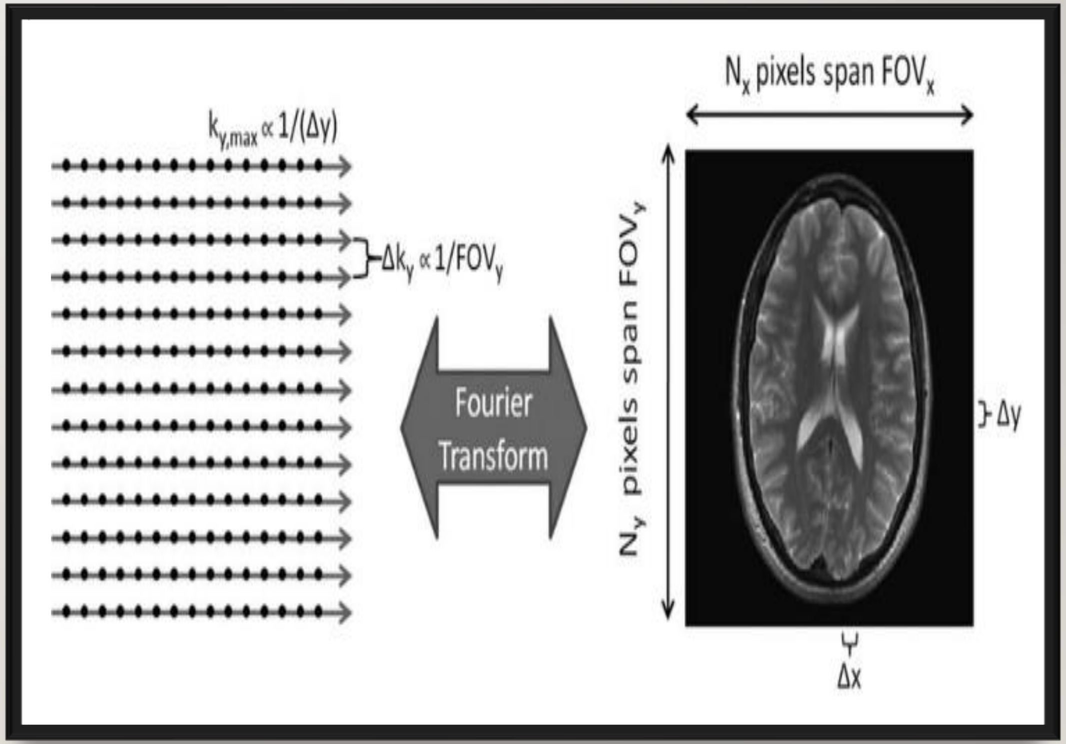
- Different MRI pulse sequences are used to encode spatial and contrast information in the acquired signal.
- Creates spatial encoding.

Types:

•**Z-gradient**: Aligns the spins along the z-axis.

•**X-gradient**: Creates spatial variation along the x-axis.

•**Y-gradient**: Creates spatial variation along the y-axis.



UNDERLYING PHYSICS OF MRI TRAJECTORIES

Fourier Transform:

- Converts k-space data to image space.
- Generates the final image.

Two types of Fourier Transform employed in MRI:

1. **2D Fourier Transform**: For 2D images, data is collected in a 2D k-space, and a 2D Fourier Transform is applied to reconstruct the image.

2. **3D Fourier Transform**: For 3D images, data is collected in a 3D k-space, and a 3D Fourier Transform is applied for image reconstruction.

FACTORS AFFECTING IN CHOOSING A TRAJECTORY

Speed: Some trajectories allow for faster data acquisition, which is crucial for dynamic studies or reducing scan times.

Resolution: The ability to accurately sample high spatial frequencies, impacting the clarity and detail of the final image.

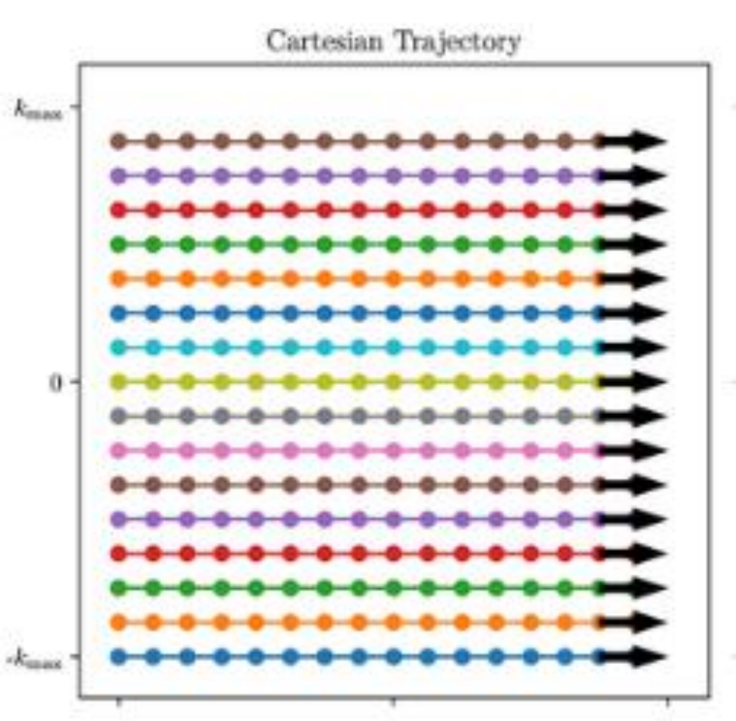
Motion Sensitivity: Trajectories less sensitive to motion are preferred for imaging moving organs.

Artifact Susceptibility: Different trajectories have varying susceptibilities to artifacts like distortions and blurring.

Reconstruction Complexity: Some trajectories require more advanced and computationally intense reconstruction algorithms.

CARTESIAN TRAJECTORIES

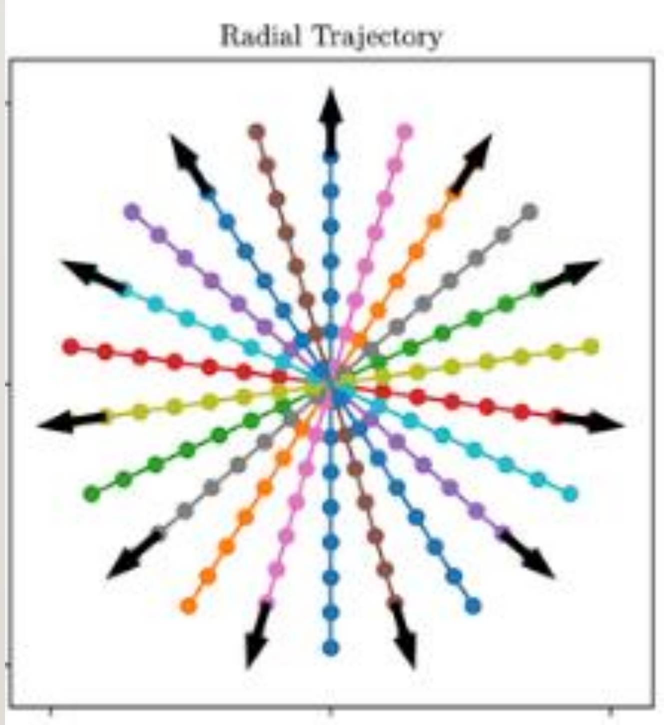
- Linear and uniform sampling.
- **Advantages:** Simple reconstruction, less sensitivity to motion.
- **Disadvantages:** Longer acquisition times, more susceptible to aliasing.



RADIAL TRAJECTORIES

Sampling along radial lines from the center.

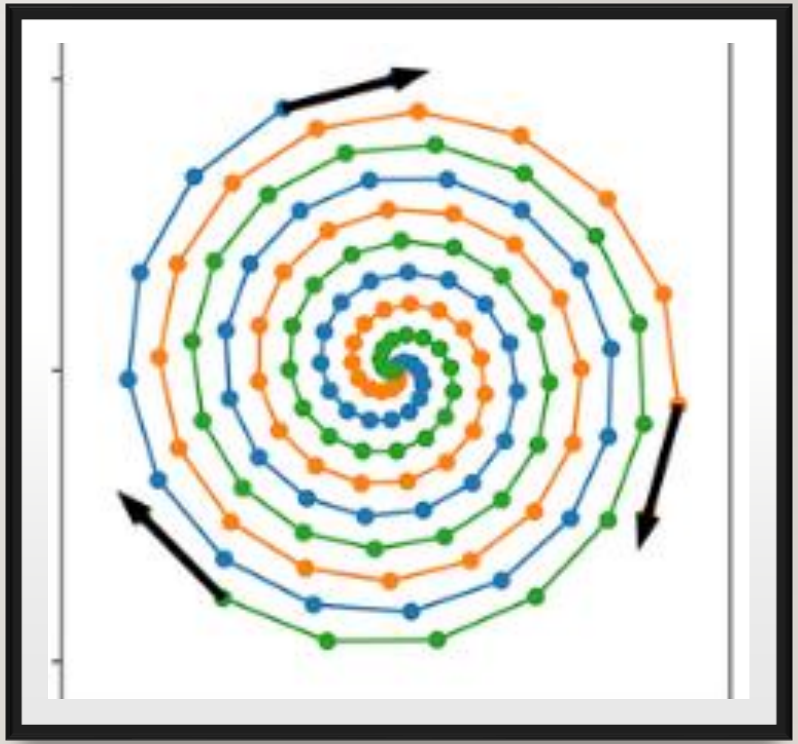
- **Advantages:** Improved motion robustness, high resolution at the center.
- **Disadvantages:** Complex reconstruction, non-uniform k-space coverage.



SPIRAL TRAJECTORIES

Continuous spiral pattern.

- **Advantages:** Fast acquisition, efficient k-space coverage.
- **Disadvantages:** Sensitive to off-resonance effects, complex reconstruction algorithms.

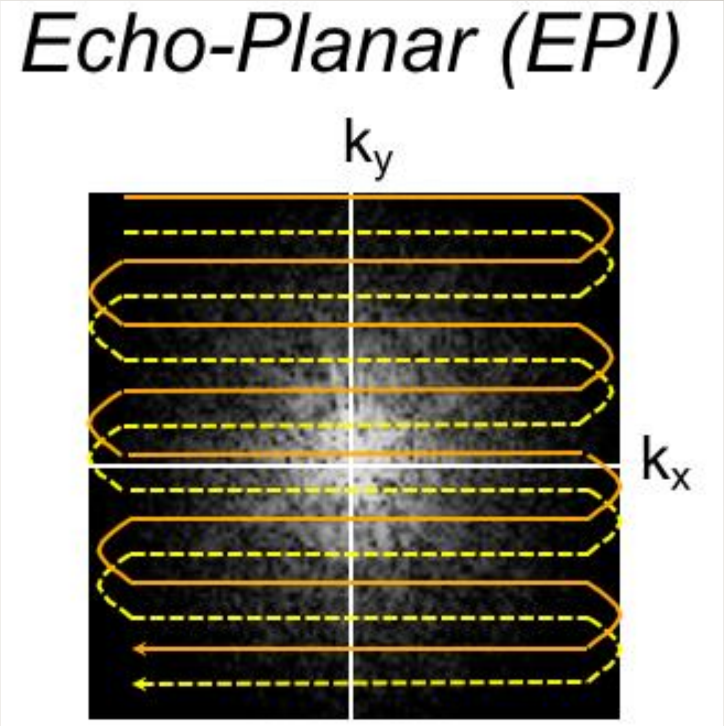


ECHO-PLANAR IMAGING (EPI)

Rapid imaging technique that samples k-space in a zigzag pattern during a single excitation.

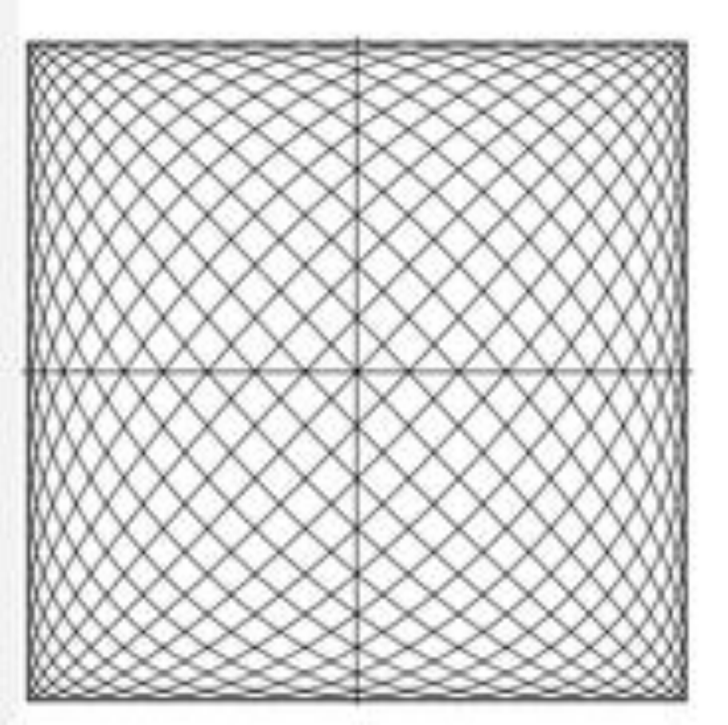
•**Advantages:** Very fast, suitable for functional MRI (fMRI) and diffusion-weighted imaging.

•**Disadvantages:** Susceptible to artifacts such as distortion and blurring, particularly in regions with large susceptibility variations (e.g., air-tissue interfaces).



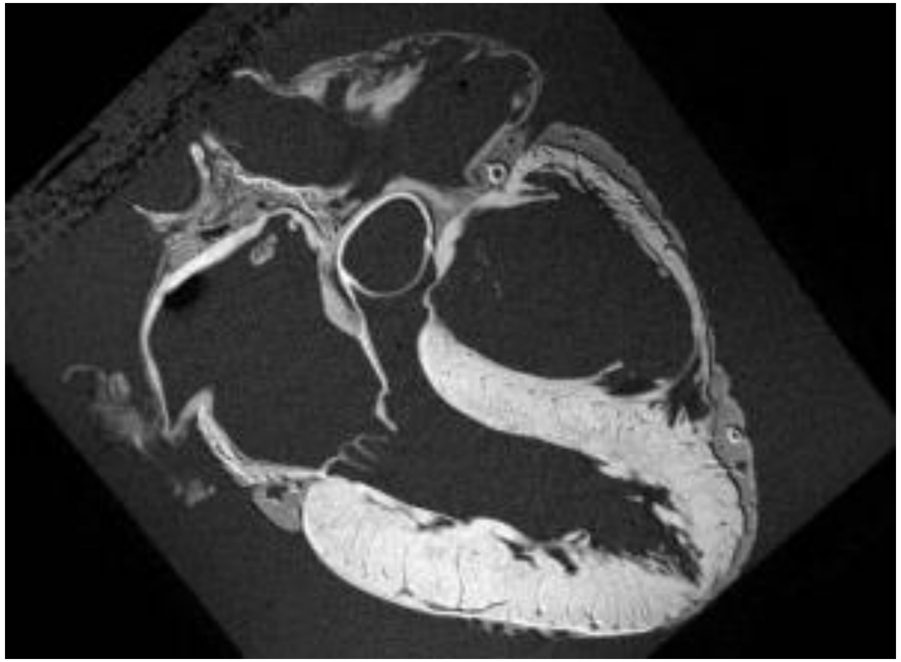
NON-CARTESIAN TRAJECTORIES

- **Examples:** PROPELLER (periodically rotated overlapping parallel lines with enhanced reconstruction), Lissajous curves.
- **Advantages:** Flexibility in design, potential for faster imaging.
- **Disadvantages:** Complex reconstruction, increased computational demand.



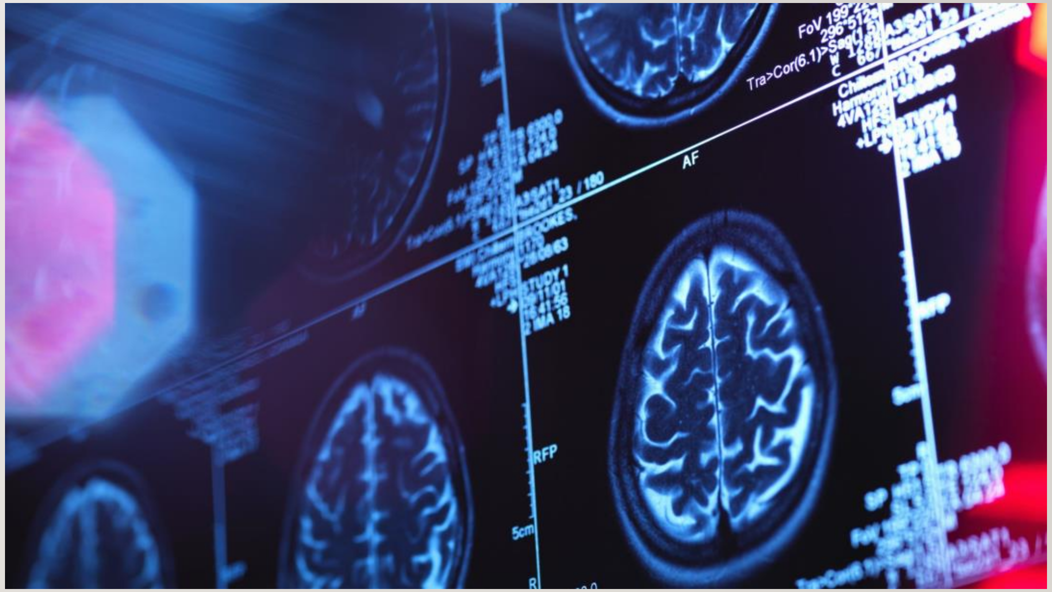
CLINICAL APPLICATIONS EXAMPLE 1: CARDIAC MRI

- **Trajectory Type:** Radial and spiral trajectories.
- **Benefits:** Reduced motion artifacts, higher temporal resolution.
- **Clinical Impact:** Improved diagnosis of cardiac conditions, better visualization of heart function.



EXAMPLE 2: FUNCTIONAL MRI

- **Trajectory Type:** Spiral trajectories.
- **Benefits:** Rapid data acquisition, better temporal resolution.
- **Clinical Impact:** Enhanced brain mapping, better understanding of brain activity.



RECENT ADVANCEMENTS

Compressed sensing techniques.

- **Adaptive Compressed Sensing**: Adaptively adjusts the sampling pattern based on intermediate reconstruction results.
- **Multiscale CS**: Combining CS with multiscale image representations.
- **Real-Time CS**: Enable real-time image reconstruction, facilitating applications in interventional MRI.

Application

- **Faster Imaging**: By reducing the number of phase-encoding steps required.
- **Improved Temporal Resolution**: In dynamic imaging by under-sampling k-space data.
- **Enhanced Image Quality**: By reducing artifacts and noise.

RECENT ADVANCEMENTS

Machine learning for image reconstruction

- **End-to-End Reconstruction Networks**: Fully automated networks takes raw k-space data as input and output reconstructed images.
- **Generative Adversarial Networks (GANs)**: Improves image realism by learning from high-quality image distributions.
- **Transfer Learning**: Leverages pre-trained models on large datasets, improves reconstruction accuracy on specific clinical datasets.

Application

- **Automated Image Reconstruction**: Automates the reconstruction process, reducing the need for manual intervention.
- **Artifact Reduction**: Reduces artifacts such as motion blur and noise.
- **Speed and Efficiency**: Significantly faster than traditional iterative methods, suitable for real-time applications.

RECENT ADVANCEMENTS

Hybrid trajectories for optimized imaging

- **Radial-Cartesian Hybrids**: Radial sampling for robust initial acquisition and transition to Cartesian sampling for detailed information.
- **Spiral-Cartesian Hybrids**: Rapid acquisition of spiral trajectories combined with detailed spatial encoding of Cartesian sampling.
- **Adaptive Hybrid Trajectories**: Adapts trajectory in real-time based on patient-specific factors or intermediate image quality assessments.

Application

- **Motion Robustness**: Reduces sensitivity to patient motion, suitable for abdominal and cardiac imaging.
- **Efficient Sampling**: Efficient k-space coverage with fewer samples.
- **High-Resolution Imaging**: By optimizing the distribution of k-space samples.

CONCLUSION

Summary: Trajectories in MRI play a crucial role in determining image quality and acquisition efficiency.

Future Directions: Continued advancements in trajectory design and reconstruction techniques hold promise for further enhancing MRI capabilities.

REFERENCES

- Y. Liu et al., "Deep Learning for Accelerated MRI Using Incoherent Sampling," *IEEE Transactions on Medical Imaging*, vol. 39, no. 2, pp. 377-387, Feb. 2020.
- A. C. Larson et al., "A Comprehensive Review of MRI Techniques for Motion Compensation and Artifact Reduction," *Magnetic Resonance in Medicine*, vol. 84, no. 1, pp. 471-488, Jan. 2022.
- A, V Kouwe et al., “Acquisition Methods and Modeling,” *Brain Mapping*, 2015.
- A. Deshmane et al., “Parallel MR Imaging”, *Journal of Magnetic Resonance Imaging*, vol. 36(1), pp 55-72, July 2012.
- Y. Wei et al., “Multi-nuclear magnetic resonance spectroscopy: state of the art and future directions,” *Insights into imaging*, 13, Art135, 2022.

THANK YOU!
ANY QUESTIONS?