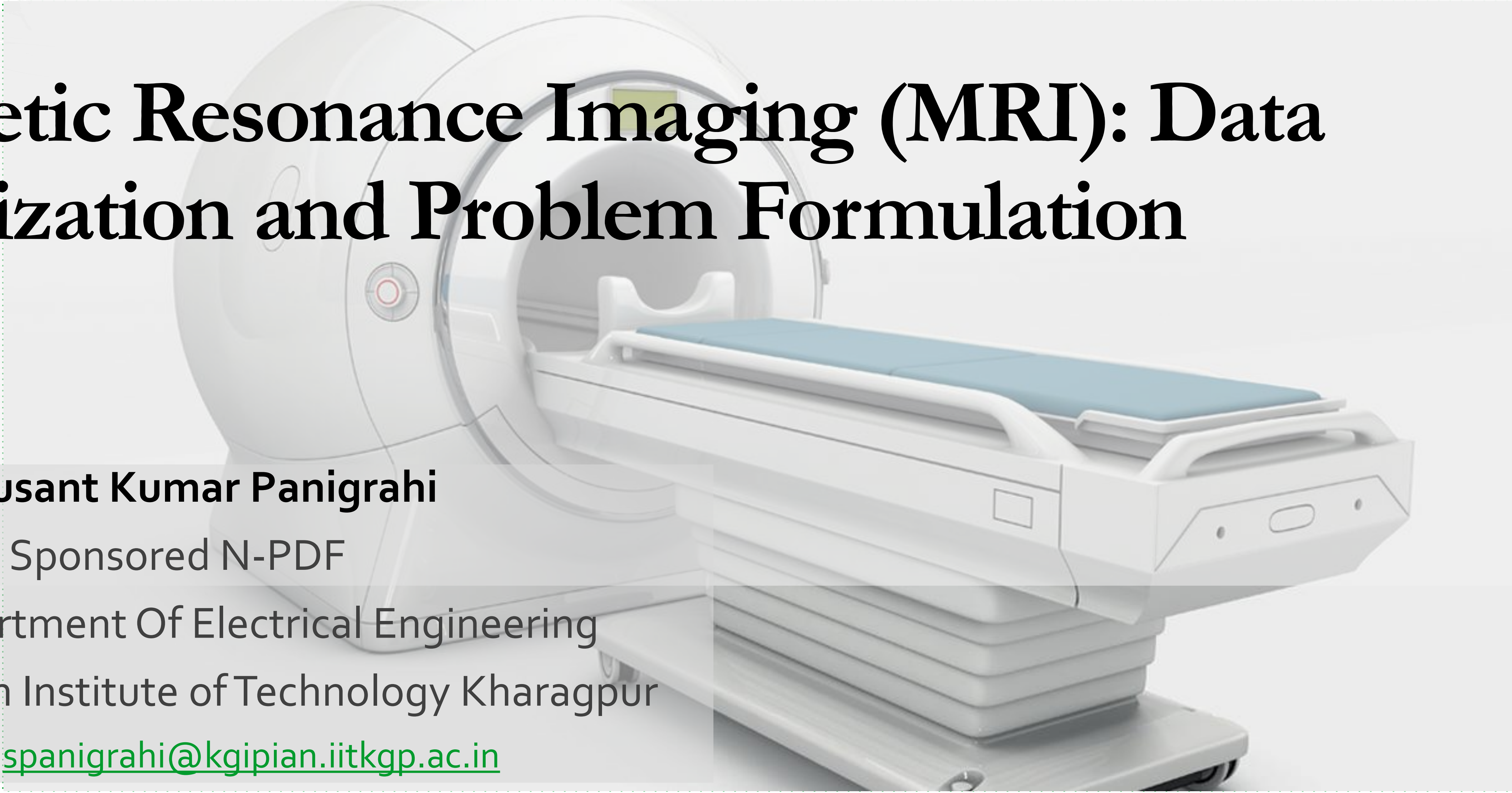
2nd National Symposium on Innovations in Intelligent Systems (2025)

School of Electrical and Electronics Engineering (SEEE)



Magnetic Resonance Imaging (MRI): Data Visualization and Problem Formulation

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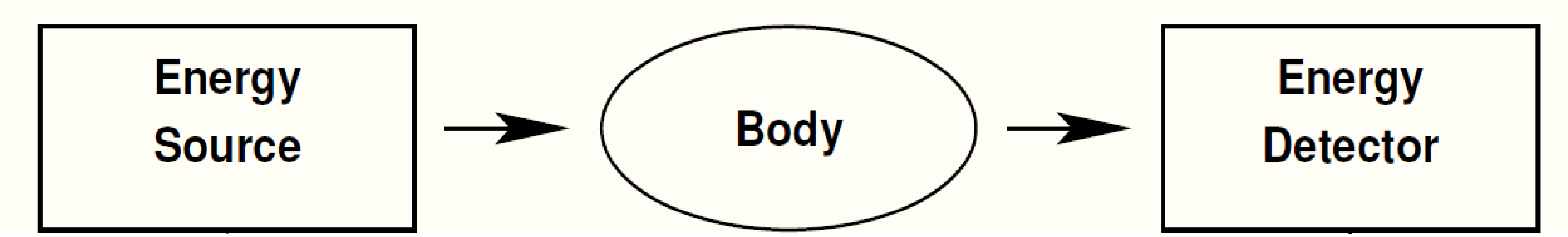
Energy Source → Tissue Property → Image Property



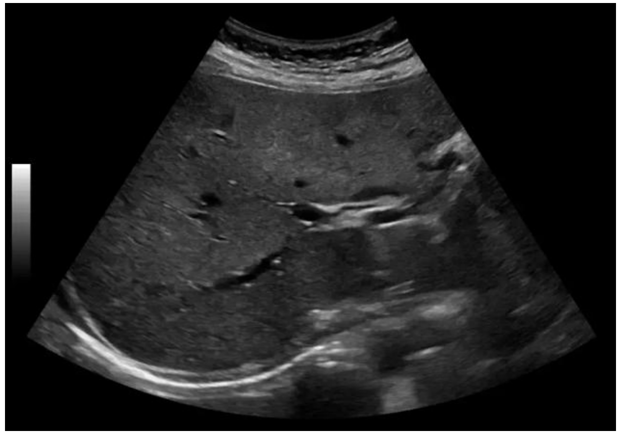
Energy Source
- X-rays
- Gamma rays
- Visible light
- Electric field
- Magnetic field
- Infrared
- Ultrasound
- Applied Voltage

Tissue Property
- Electron density
- Mass density
- Proton density
- Atomic Number
- Temperature
- Oxygenation
- Chemical state

Image Property
- Transmissivity
- Emissivity
- Reflectivity
- Conductivity
- Magnetizability
- Resonance
- Absorption

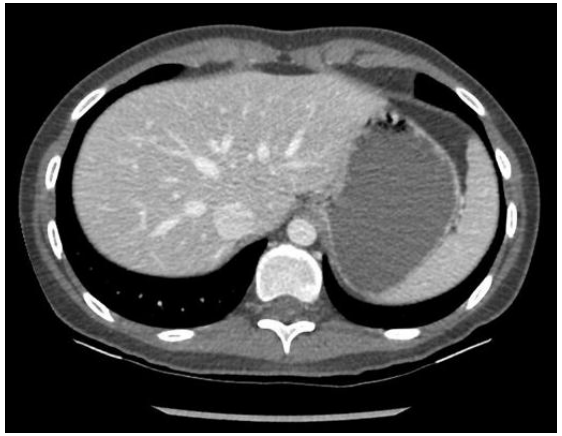
Imaging: What different modalities measure ?

U/S



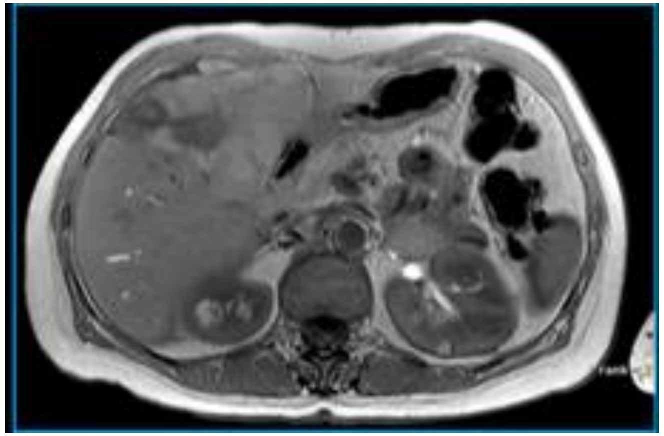
Reflectivity
Characteristic impedances → Density x Bulk modulus
0.2 -0.3 mm

CT



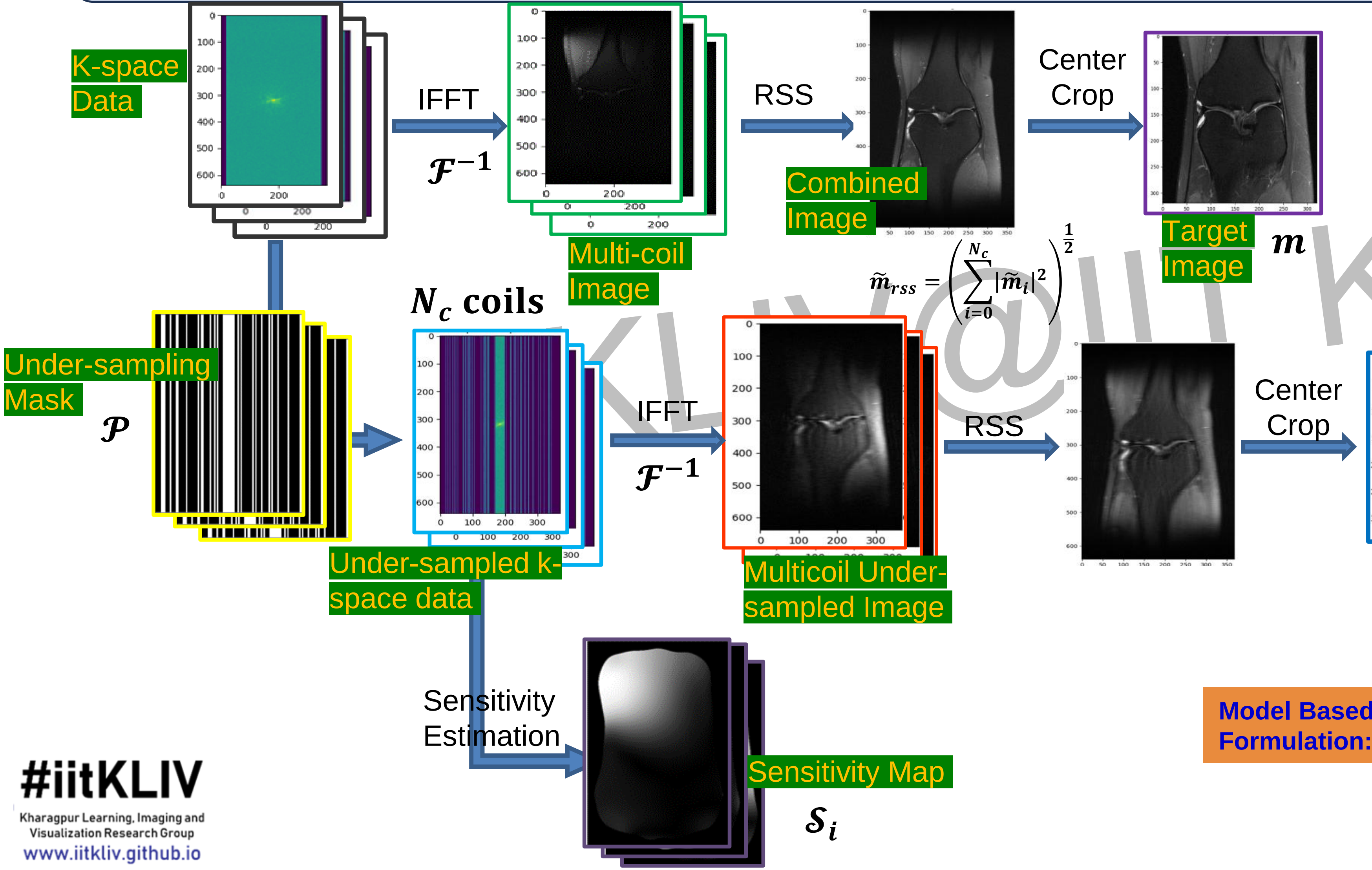
X-Ray, Absorption
Electron Density
Resolution = 0.2-0.5 mm mm

MRI



Resonance
Magnetizability
Proton Density
Resolution = 0.5-1.0 mm

Parallel Imaging: Deep Learning-Based Reconstruction for Accelerated Magnetic Resonance Imaging (MRI)



The Problem Formulation:

$$\boldsymbol{y_i} = \boldsymbol{A_i m} + \boldsymbol{\eta}, \qquad \forall i = 1, 2, \cdots, N_c$$

$$\boldsymbol{A_i} = \mathcal{P} \odot \mathcal{F}(\mathcal{S}_i m)$$

$$\widetilde{\boldsymbol{m}}_i = \mathcal{F}^{-1}(\boldsymbol{y_i})$$

Model Based Recon. Formulation:

$$\widehat{\boldsymbol{m}} = \mathcal{B}(\boldsymbol{y})$$

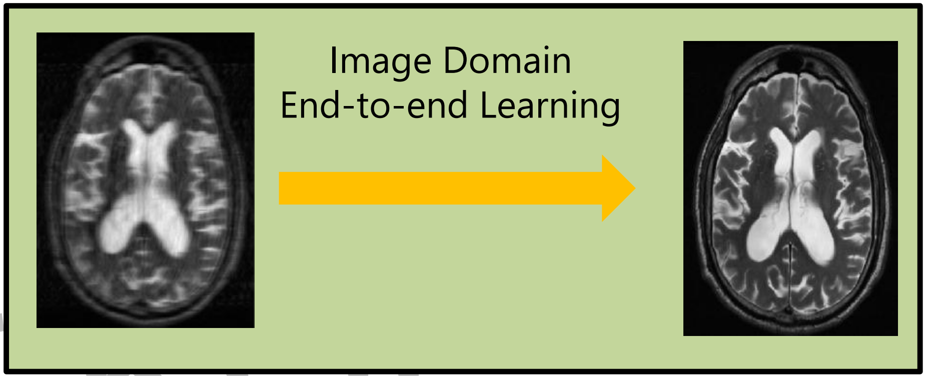
$$\mathcal{B}^* = \arg\min_{\mathcal{B}} \boldsymbol{R}(\mathcal{B})$$

$$R(\mathcal{B}) = \mathbb{E}_{(y,m)}[L(\mathcal{B}(y), m)]$$

$$R_{emperical}(\mathcal{B}) = \frac{1}{n_{data}} \sum_{i=1}^{n_{data}} L\left(\mathcal{B}\left(y^{(i)}\right), m^{(i)}\right)$$

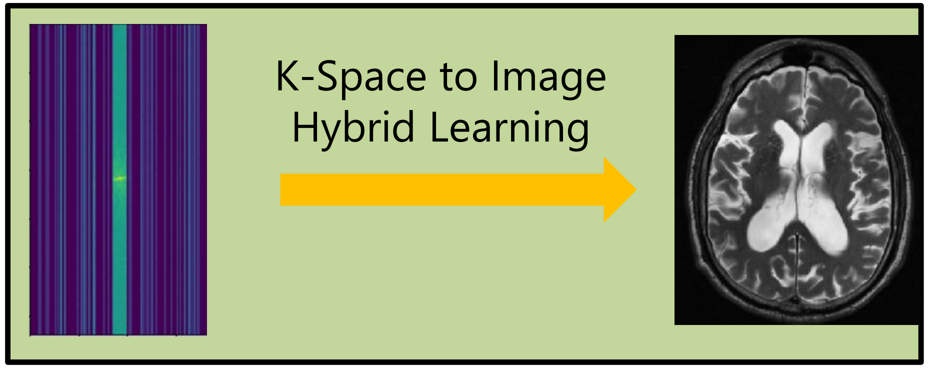
Problem statement 1: **Image-Domain End-to-End Learning for MRI Reconstruction**

Develop deep learning models that operate directly in the image domain to reconstruct high-quality MR images from undersampled k-space data, focusing on reducing artifacts and preserving anatomical details.



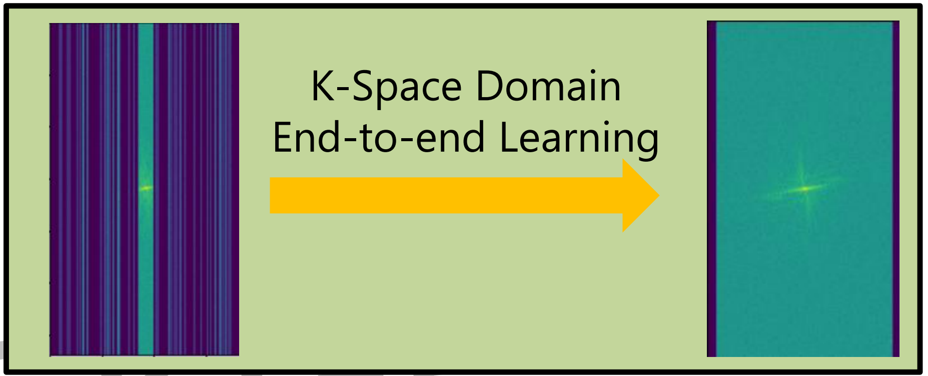
Problem statement 2: **Hybrid Learning from K-Space to Image Domain:**

Design hybrid models that leverage information from both k-space and image domains to improve MRI reconstruction by combining spatial frequency and spatial domain features for enhanced accuracy and artifact suppression.



Problem statement 3: K-Space Domain End-to-End Learning for MRI Reconstruction

Create deep learning frameworks that operate exclusively in the k-space domain to directly reconstruct fully sampled k-space data from undersampled inputs, ensuring accurate recovery of high-frequency details.



Problem statement 4: Model-Based Unrolling for Iterative MRI Reconstruction

Develop physics-informed deep learning methods that unroll traditional iterative reconstruction algorithms into trainable neural networks, leveraging MR physics models to enhance image quality and accelerate reconstruction from undersampled k-space data.

Model-based unrolling iterative deep learning MR image reconstruction