National Institute of Technology Rourkela

Synopsis Seminar

Seminar Title	: Integrating Traditional to Deep Learning Approaches for Classification of Subsurface Objects by Ground Penetrating Radar
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Venue	: EC seminar hall (EC 303), Department of ECE
Date and Time	: 30 Jun 2025 (4PM)

Abstract

: Ground Penetrating Radar (GPR) is a non-invasive sensing technology widely used for subsurface imaging. While its ability to detect buried objects is well-established, GPR signal interpretation remains challenging due to the presence of clutter and noise arising from surface reflections, antenna coupling, and subsurface inhomogeneities. These artifacts often obscure true reflections from targets, making effective clutter removal a critical preprocessing step for subsequent tasks like object classification. This thesis presents a comprehensive and progressive research framework for clutter suppression and classification in GPR imagery. It begins with traditional signal processing techniques, focusing on gradient-based filtering and eigen-image decomposition for homogeneous sandy environments. These foundational methods provided valuable insights into clutter characteristics but are limited in their ability to handle overlapping targets or inhomogeneous terrains. To improve clutter separation, a topological active net (TAN)-based segmentation method, combined with a hyperbola-fitting optimization filter, is developed to isolate hyperbolic target signatures more accurately. Following this, the research introduces a deep learning-based framework, Spatial Attention-based Convoluted Gazelle Neural Network (SACGNN), designed specifically for advanced clutter suppression. SACGNN utilizes an encoder-decoder architecture embedded with spatial attention blocks and multi-scale convolutional layers to preserve target features while removing clutter. This model is rigorously validated across diverse synthetic, experimental, and open-source datasets. Building upon the clutter-free outputs, a robust classification model named Bidirectional Focal Tversky Dynamic Multiscale Convolutional Neural Network based on AlexNet (BFDMCA) is proposed. It integrates dynamic multiscale convolutional modules and a Focal Tversky loss function to emphasize hard-to-classify samples while addressing class imbalance. To address data scarcity, Conditional GAN (cGAN)-based augmentation is used to generate varied and realistic training samples. Model interpretability is enhanced using SHapley Additive Explanations (SHAP), enabling visualization of feature contributions for each prediction.

In summary, the thesis presents a unified GPR analysis pipeline that spans traditional clutter removal, deep learning-based enhancement, and explainable classification. The proposed methodologies offer scalable, accurate, and interpretable solutions for subsurface object detection, setting the stage for real-world deployment in challenging environments.