Synopsis Seminar

Seminar Title	: Enhancing GPR Signal Processing Methods for Clutter Reduction and Velocity Estimation
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Abstract : **Ground penetrating radar (GPR) has become a popular tool for non-invasive investigation of subsurface media and buried objects. It is widely used in various applications, like, archeological survey, civil engineering infrastructure mapping, structural assessment of tunnels and bridges, utility mapping, environment monitoring, etc. GPR solutions are also proposed for defense applications, like, detections of landmines and unexploded ordnances, tunnels, space exploration to study planet surface, etc. Often GPR data is very complex to interpret, application specific, requires lot of expertise to interpret. The GPR data contains unwanted reflections, noise, and artifacts caused by various sources such as surface roughness, electromagnetic interference, and heterogeneous subsurface media properties. These unwanted reflections are known as clutter which hinders the detection of subsurface scenarios. Additionally, the effect of clutter becomes more severe for shallow buried targets, because in such scenarios, the clutter often masks the target reflections. Hence, its removal in GPR data is crucial for enhancing the quality and accuracy of subsurface imaging and interpretation. Moreover, clutter removal facilitates the extraction of reliable information about the subsurface velocity. The subsurface velocity estimation is a fundamental step in GPR data processing for precise localization and detection of the buried target. However, the unpredictable nature of GPR data, caused by variations in subsurface conditions, makes this task challenging. So far, there is no reliable technique available for velocity estimation which can work for different soil conditions as well as target scenarios. Therefore, sophisticated signal processing techniques are required for effective clutter removal and accurate subsurface velocity estimation. Both steps are crucial for maximizing the utility and reliability of GPR in subsurface exploration. The main aim of this thesis is to enhance the signal processing techniques for efficient clutter suppression and media characterization to have an improved GPR investigation.**

There are many velocity estimation schemes developed for different types of GPR configurations, target scenarios. However, their performance is severely compromised as the data is corrupted by noise and clutter. A detailed analysis of subsurface velocity estimation methods to assess their applicability across various subsurface profiles has been done to know their performances in synthetic as well as experimental data. A significant contribution is done in the field of velocity estimation by proposing novel methods as well as improving few important steps of clustering, hyperbola detection, and subsequently velocity estimation. Velocity estimation helps better imaging and localization of objects. GPR imaging is an important step for localization and identification of objects. The migration and reverse time migration are the popular tools used for subsurface imaging. Among migration approaches, the commonly used schemes are hyperbolic summation (HS), Kirchhoff&rsquos migration (KM), frequency wavenumber (FK) migration. The effectiveness of these imaging techniques depends significantly on the accuracy of the velocity estimates. Errors in velocity estimation can result in improper focusing, leading to over- or under- migration of hyperbolic signatures. This GPR imaging concept is leveraged to indirectly estimate the subsurface velocity from a range of trial velocities.

The above velocity estimation and subsurface imaging are performed after the clutter reduction by employing the traditional approaches for clutter removal. However, there are certain drawbacks of traditional clutter removal approaches. They may leave residual clutter or they are not effective in complex GPR scenarios like roughness enabled subsurface. Additionally, some approaches are dependent upon factors like regularization parameter which cannot be generalized across diverse profiles. In order to overcome these limitations of traditional clutter removal approaches, a deep learning based Attention U-Net is proposed for the effective suppression of clutter in real world GPR images. The proposed architecture integrates a channel attention modules (CAM) and spatial attention module (SAM) into the base U-Net model to effectively learn the clutter distribution in the data and successfully remove the clutter. Additionally, a deep learning based lower complexity network known as Laplacian Enabled U-Net is proposed for clutter removal with reduced computational requirements. The proposed approach integrate a mean followed by Laplacian filtering along the skip connections of a base U-Net model. The efficacy of these proposed methods are compared with several state-of-the-art approaches on both simulated and laboratory measured data, through qualitative and quantitative evaluation.

In this thesis several analytical and machine learning and deep learning approaches have been developed to improve velocity estimation and clutter removal in different types of GPR scenarios. These techniques are valuable tool for GPR signal processing and important steps for future research in developing reliable and effective clutter removal and velocity estimation techniques for complicated scenarios.