2024-2025 Undergraduate Research Award Application

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Georgia Southern University

ConcreteNet: A Deep Convolutional Neural Network for Deformity Detection and Classification in Ground-Penetrating Radar Images

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ABSTRACT

The integrity of concrete structures is essential for public safety and infrastructure longevity. Non-destructive testing (NDT) methods are used for inspection and assessment of concrete structures. However, traditional NDT methods, particularly ground-penetrating radar (GPR), face challenges in analyzing complex and noisy radargram data. To address these limitations, we propose ConcreteNet, a discriminative convolutional neural network optimized for GPR radargram classification. ConcreteNet leverages the "Network in Network" architecture, with AlexNet serving as the base model, to detect structural defects more effectively. The model will be trained on radargram data from recent scans of the Georgia Southern Engineering Research Building and validated using pre-existing GPR data from the Georgia Department of Transportation. Additionally, the creation of a publicly accessible GPR radargram dataset is a critical component of this research that warrants a paper of its own. Given the limited availability of GPR data, such a dataset would greatly facilitate researchers in training deformity detection models in this field. Benchmarking this dataset against state-of-the-art classification and object detection networks will further refine GPR-based deformity detection in concrete.

TOTAL BUDGET AMOUNT

$1,000

By accepting this award, I understand my obligation to present a poster at the PCEC Research Symposium on April 25, 2025.

Anish Goyal
Student Signature

Hossein Taheri
Faculty Mentor Signature

I. PROJECT NARRATIVE

A. Description

The continual assessment of concrete is used to guide decisions regarding repairs and maintenance of critical infrastructure. One of the most effective assessment techniques is nondestructive testing (NDT), which allows engineers to gather vital information about the internal condition of a concrete structure without causing physical damage. Among the various NDT methods, ground-penetrating radar (GPR) is particularly valuable for its ability to provide detailed radargram images of concrete structures. However, GPR data is often noisy, making manual interpretation prone to errors. Despite these challenges, recent advancements in computer vision, specifically convolutional neural networks (CNNs), offer a promising solution. CNNs excel at recognizing patterns and features in images, making them ideal for automating the detection of anomalies within GPR data, leading to faster, more accurate assessments of concrete defects. This research project aims to develop a specialized CNN model, ConcreteNet, tailored specifically for the classification and detection of anomalies in GPR radargrams. Furthermore, this research will generate two key outcomes: (1) a neural network architecture optimized for GPR radargram analysis, and (2) a publicly available dataset of GPR scans that will serve as a benchmark for future work. The dataset will be evaluated using state-of-the-art models in image classification, object detection, and weakly supervised object detection (WSOD) to demonstrate its utility as a benchmark. This will generate two academic papers—one focusing on the development and validation of ConcreteNet, and the other on the creation and benchmarking of the dataset against state-of-the-art models.

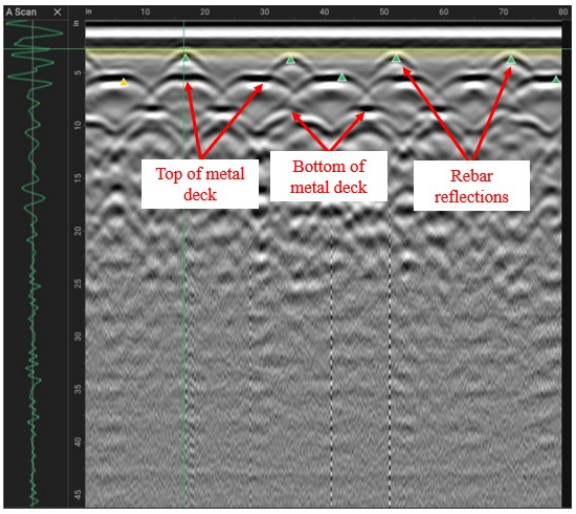

FIG. 1. Sample B-Scan GPR Radargram

B. Experimental Plan

The first part of this project will focus on developing the architecture of ConcreteNet. The model will be based on the AlexNet architecture, enhanced using a "Network in Network" approach to capture the subtle and complex features within GPR data. The model will be trained using floor scans from the Georgia Southern Engineering Research Building, chosen for its recent construction date and contemporary design. To simulate structural deformities such as delamination, corrosion, honeycombing, and voids, we will embed these defects into concrete slabs in a controlled laboratory setup, where each type of defect will be introduced at varying depths (from 1 to 5 inches), and add the resulting data to the training set. After the model is trained, it will be validated using existing GPR data provided by the Georgia Department of Transportation, using common metrics such as accuracy, precision, recall, and F1-score to evaluate its performance. For the second part of the project, the training dataset will be benchmarked against state-of-the-art computer vision models to measure cross-dataset model performance and prove the generalization capabilities of each model on the new dataset. The goal is to prove that this dataset poses a significant challenge due to its high intra-class variability, which reflects the diverse and noisy nature of GPR radargrams. We will benchmark this dataset against various cutting-edge models in image classification, object detection, and weakly supervised object detection (WSOD) to demonstrate its difficulty compared to ConcreteNet's performance. For image classification, MobileNet, DenseNet121, and ResNet50 will be tested. For object detection, YOLOv11, RetinaNet, and Faster-RCNN will be evaluated. For WSOD, Wetectron, C-MIL, and PCL will be assessed.

C. Expected Outcomes

- Poster presentation at the PCEC and Georgia Southern University-wide Student Research Symposiums
- Prospective journals: ASNT Journals of Materials Evaluation and Research in Nondestructive Evaluation
- Prospective presentations: ASNT Research Symposium and ASME-IMECE Conference

II. ITEMIZED BUDGET WITH JUSTIFICATION

A. Budget Breakdown and Justification

Item	Amount	Justification
Software and Licensing	$700	Essential for neural network training, image processing, and data analysis.
Materials and Supplies	$300	Necessary for data storage and collection hardware; also, experimentation.
Total	**$1,000**	