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Diagnostic Imaging of Structural Concrete Using Ground Penetrating Radar and Ultrasonic Array

Sina Mehdinia
Portland State University

Thomas Schumacher
Portland State University

Eric Wan
Portland State University

Xubo Song
Oregon Health and Science University

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Sina Mehdinia[1], Thomas Schumacher[1], Eric Wan[1], and Xubo Song[2]
[1]Portland State University, [2]Oregon Health and Science University

iSTAR Laboratory
infraStructure Testing and Applied Research

Motivation

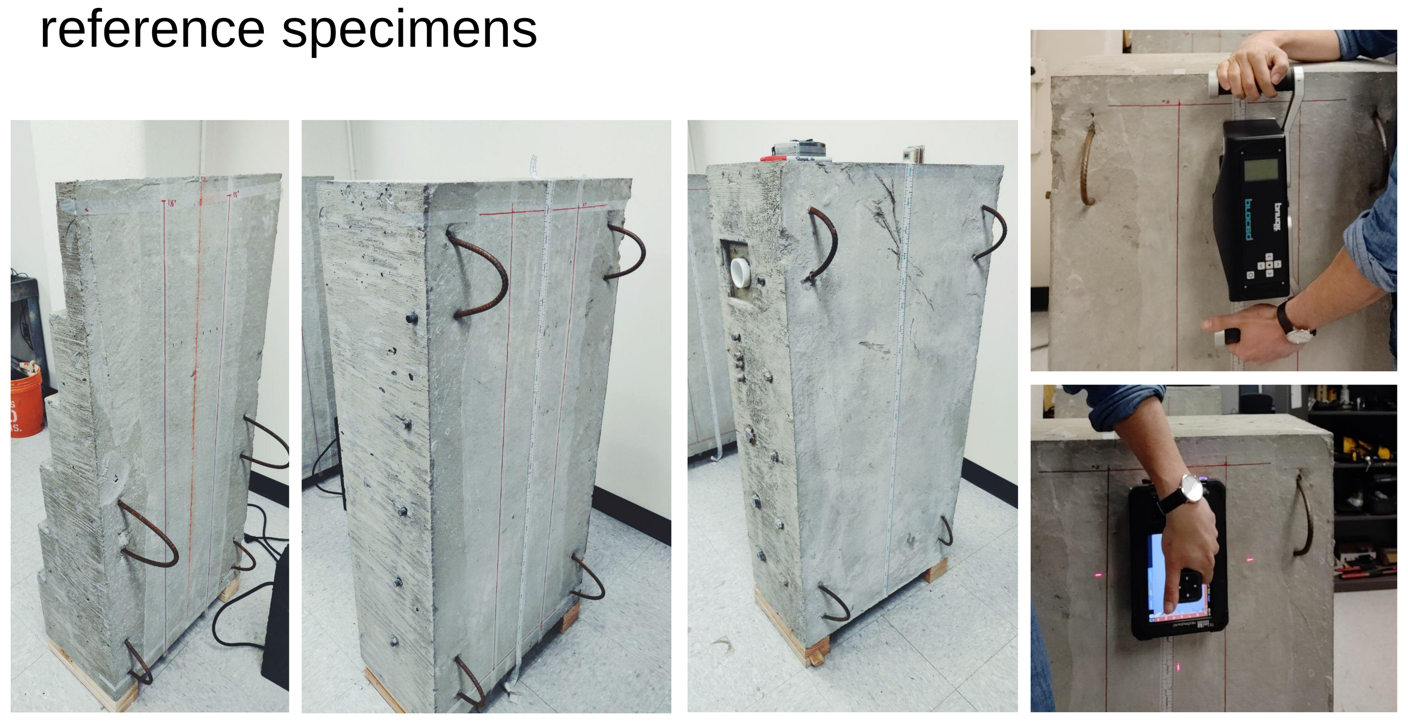
Structural concrete is the most widely used construction material in the world. After an extreme event such as an earthquake, fast and reliable condition assessment is key to ensure effective and safe disaster relief missions. This is of particular concern for the Pacific Northwest with a mega-thrust earthquake waiting to occur. While ultrasound and radar techniques exist to map the interior of concrete, they have individual strengths and limitations and are not integrated. Advances in medical imaging and machine learning offer opportunities to create such tools.

Objective

Create diagnostic image solution for structural concrete by integrating the most recent advances in non-destructive testing, medical imaging, and machine learning.

Research Tasks

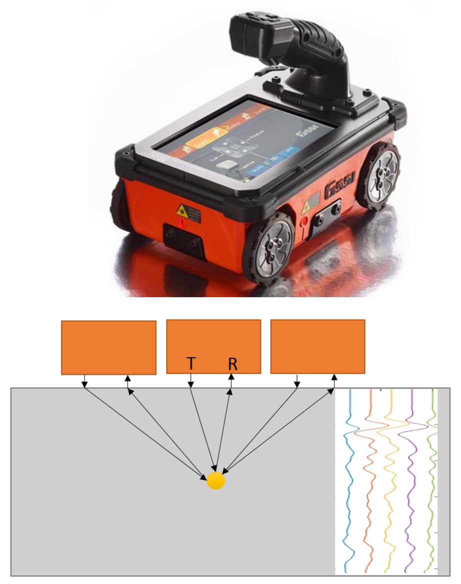
- Construction of reference specimens with known geometries and location of steel reinforcement bars
- Collect measurements using two modalities: ground penetrating radar (GPR) and ultrasound (US)
- Establish and verify data processing and image fusion algorithms using measurements from reference specimens



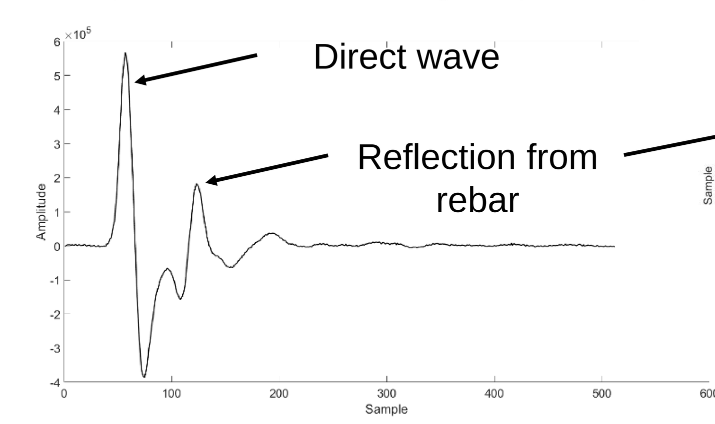
Reference specimens set up in the laboratory for taking measurements: Specimens 1 to 3 (from left to right).
Top right: ultrasonic array instrument, bottom right: radar instrument.

Modality 1: Ground Penetrating Radar (GPR)

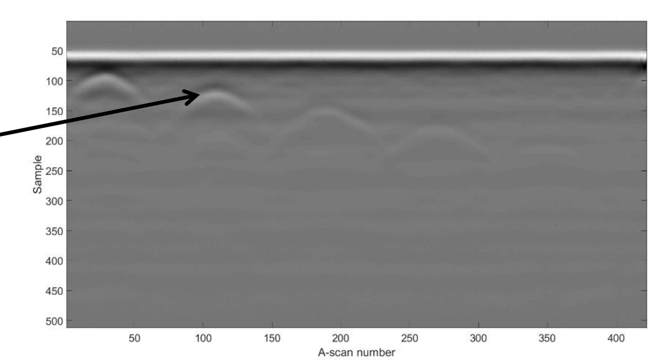
- An electromagnetic pulse is transmitted into the material along a path on the surface
- The pulse is reflected when the material, i.e. the relative permittivity changes
- Pulse frequency: 2.7 GHz
- Sampling time increment, Δt = 0.0164 ns



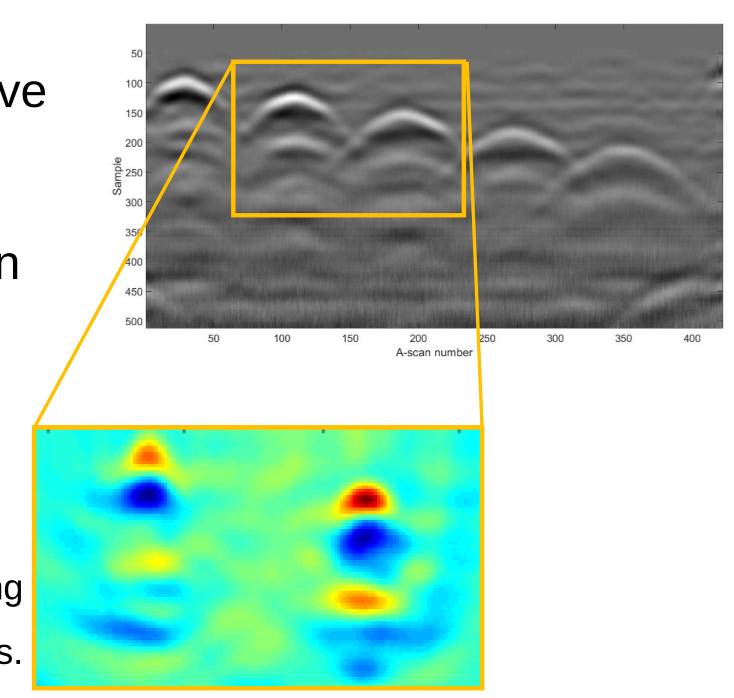
Sample recorded GPR signal (A-Scan)



A typical B-Scan (Specimen 2)



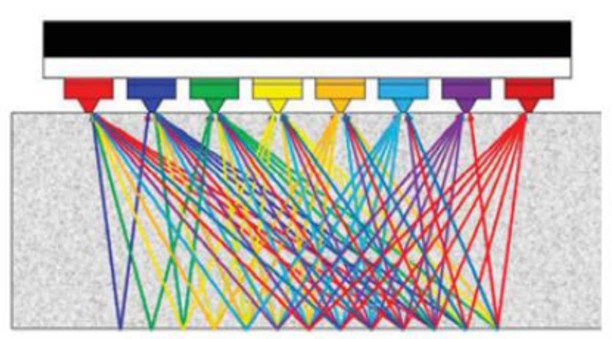
- Processing steps: Direct wave removal, attenuation correction, filtering, migration using diffraction summation



Migrated image showing actual shape of reflectors.

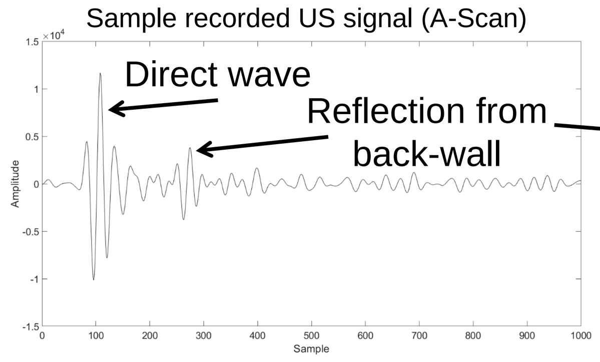
Modality 2: Ultrasound (US)

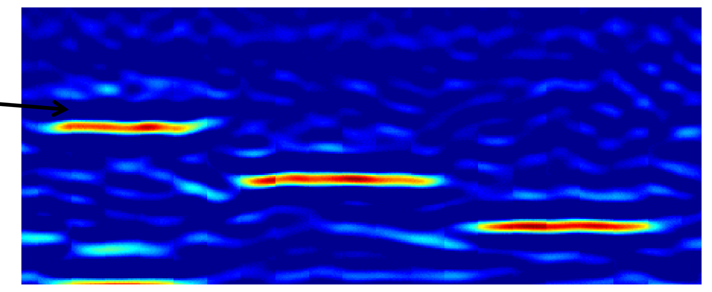
- A stress-wave pulse is sent row-by-row into the material and received by all other transducers
- The pulse is reflected when the material, i.e. the acoustic impedance changes
- Pulse frequency: 50 kHz; Sampling rate: 1 MHz.



- Processing steps: Direct wave removal, attenuation correction, filtering, panoramic image reconstruction using synthetic aperture focusing technique (SAFT)

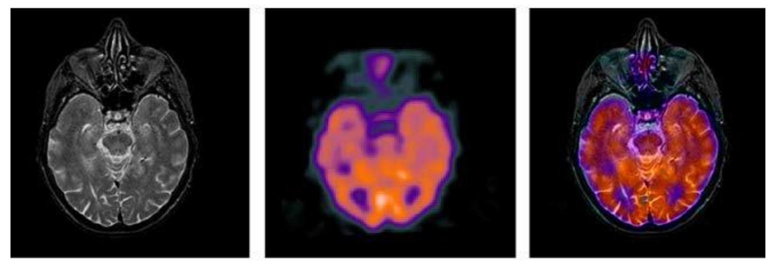
Sample recorded US signal (A-Scan)





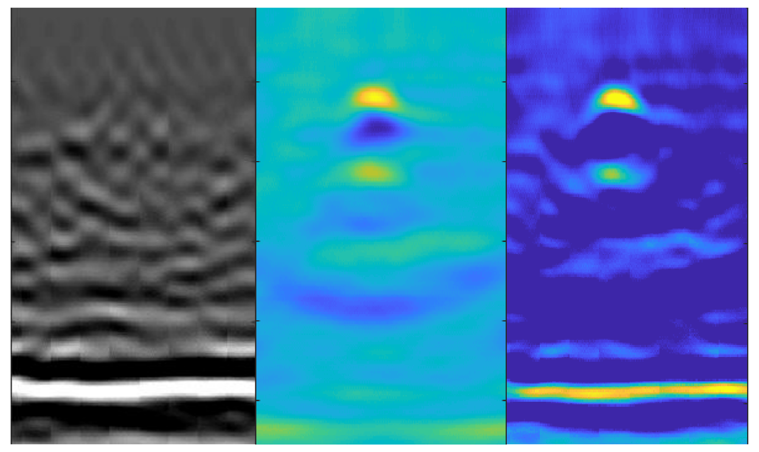
Multi-Modal Image Fusion

Image fusion is the process of combining images created from different measurement techniques to provide an enhanced image with more details. The two presented modalities are employed because:

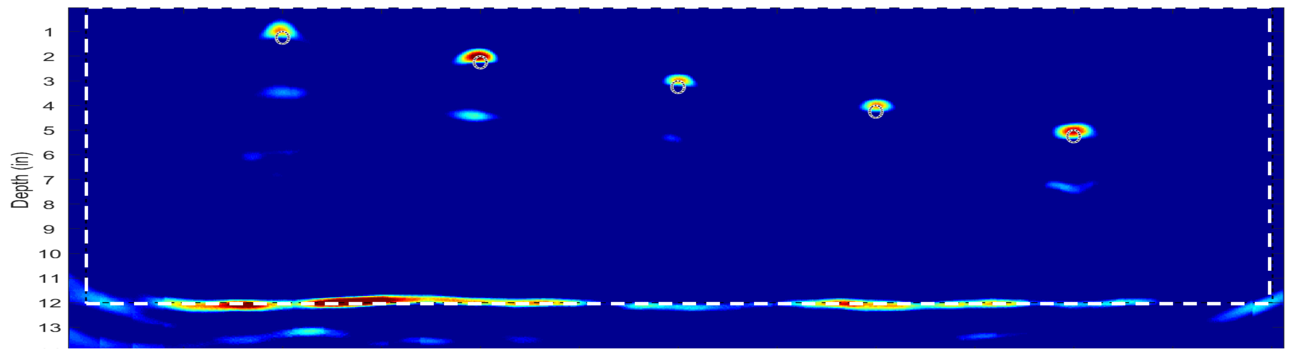


Example of medical image fusion.

- GPR is effective at detecting metallic reflectors such as steel reinforcing bars; and
- US is effective at detecting air voids and geometric boundaries.



- Example reconstruction for Specimen 2



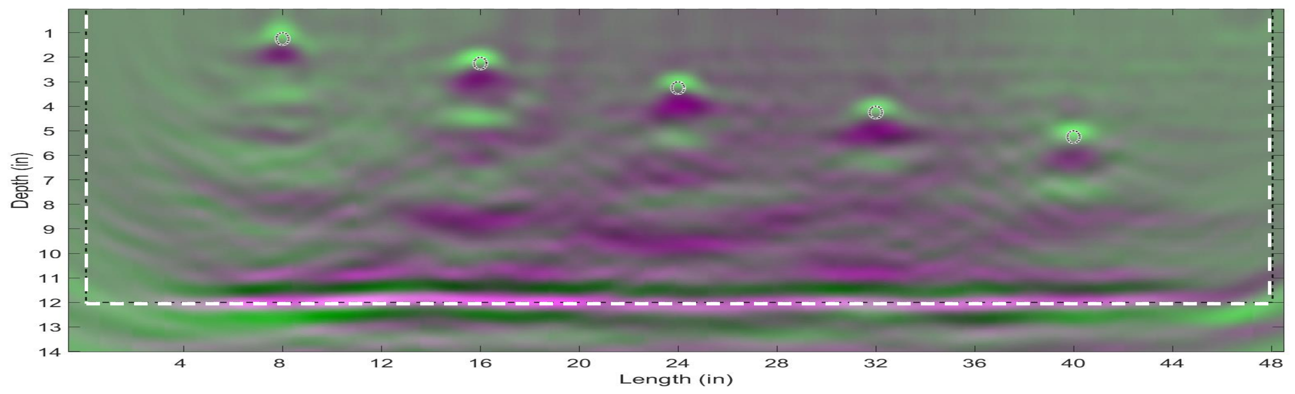


Photo (top) and fused images (middle and bottom) of Specimen 2 using blending and false coloring methods respectively

Acknowledgements

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