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# DIAGNOSTIC IMAGING OF STRUCTURAL CONCRETE

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## ABSTRACT

*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 of buildings and bridges is key to ensure effective and safe disaster relief missions. This is of particular concern for the Pacific Northwest with a megathrust earthquake waiting to occur. Accurate and reliable non-destructive testing (NDT) tools represent an important solution to aid in this task. Ground penetrating radar (GPR) uses electromagnetic waves and is especially useful in identifying and locating embedded steel reinforcing bars in the concrete. Ultrasonic (US) arrays, on the other hand, use stress waves that strongly reflect at concrete-air interfaces such as internal voids and back walls. Advances in medical imaging and machine learning offer opportunities to fuse these measurements and create novel diagnosis tools. This poster describes the first phase of a multi-disciplinary research project. It discusses how signals from both modalities, i.e. GPR and US, are obtained from a set of concrete reference specimens, how the signals are then processed to generate a visual representation of the interior, and finally how a high resolution image is obtained by image fusion to reveal details such as the location of the rebars, air voids, and the geometry of the specimen.*

Keywords: ground penetrating radar, ultrasound, image fusion, non-destructive evaluation

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# Diagnostic Imaging of Structural Concrete

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## Motivation

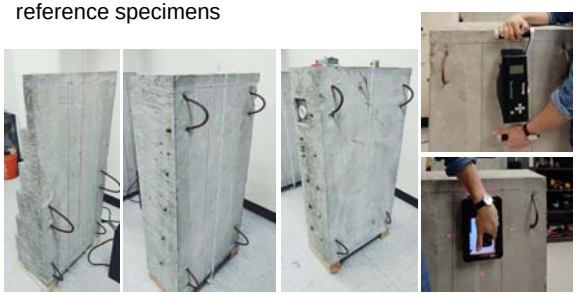
Structural concrete is the most widely used construction material in the world. After an extreme event such as an earthquake, fast and reliable condition assessment is key to ensure effective and safe disaster relief missions. This is of particular concern for the Pacific Northwest with a mega-thrust 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

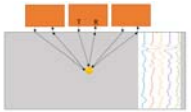
- Construction of reference specimens with known geometries and location of steel reinforcement bars
- Collect measurements using two modalities: ground penetrating radar (GPR) and ultrasound (US)
- Establish and verify data processing and image fusion algorithms using measurements from reference specimens



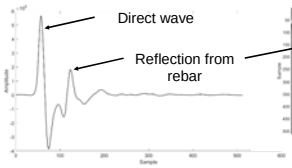
Reference specimens set up in the laboratory for taking measurements: Specimens 1 to 3 (from left to right).
Top right: ultrasonic array instrument, bottom right: radar instrument.

## Modality 1: Ground Penetrating Radar (GPR)

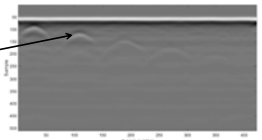
- An electromagnetic pulse is transmitted into the material along a path on the surface
- The pulse is reflected when the material, i.e. the relative permittivity changes
- Pulse frequency: 2.7 GHz
- Sampling time increment, $\Delta t$ = 0.0164 ns



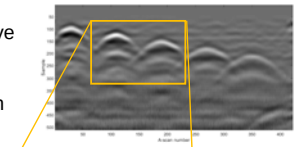
Sample recorded GPR signal (A-Scan)

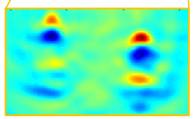



A typical B-Scan (Specimen 2)



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

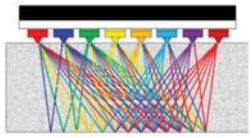




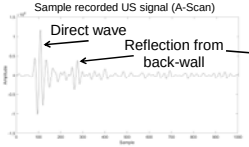
Migrated image showing actual shape of reflectors.

## Modality 2: Ultrasound (US)

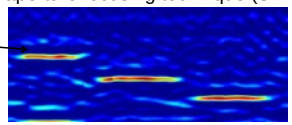
- A stress-wave pulse is sent row-by-row into the material and received by all other transducers
- The pulse is reflected when the material, i.e. the acoustic impedance changes
- Pulse frequency: 50 kHz; Sampling rate: 1 MHz.



Sample recorded US signal (A-Scan)

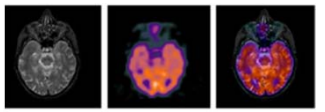



- Processing steps: Direct wave removal, attenuation correction, filtering, panoramic image reconstruction using synthetic aperture focusing technique (SAFT)



## Multi-Modal Image Fusion

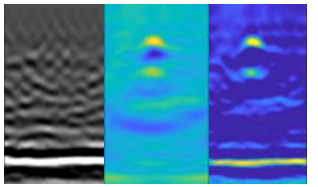
Image fusion is the process of combining images created from different measurement techniques to provide an enhanced image with more details. The two presented modalities are employed because:



MRI image SPECT image Fused image

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.



Ultrasound GPR Fused Image

- Example reconstruction for Specimen 2

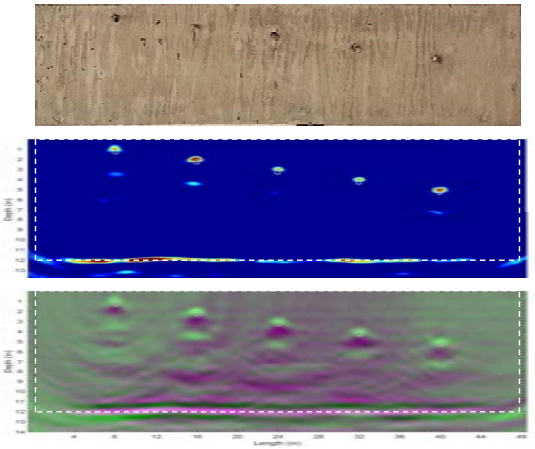


Photo (top) and fused images (middle and bottom) of Specimen 2 using blending and false coloring methods respectively

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