Progress Implementing a Model-Based Iterative Reconstruction Algorithm for Ultrasound Imaging of Thick Concrete

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All commercial nuclear power plants (NPPs) in the United States contain concrete structures. Typical concrete structures in these plants can be grouped into four general categories: primary containment buildings, containment internal structures, secondary containments/reactor buildings, and other structures, such as spent fuel pools and cooling towers. These structures provide important foundation, support, shielding, and containment functions. Identification and management of aging and degradation of concrete structures is fundamental to the proposed long-term operation of NPPs. Consequently, imaging techniques for a quantitative assessment of any safety issues related to plant aging and the acceptability of concrete structures is necessary in order to avoid premature decommission of NPPs.

Imaging of thick concrete is a challenging endeavor. Unlike most metallic materials, reinforced concrete is a nonhomogeneous material, a composite with a low-density matrix, a mixture of cement, sand, aggregate and water, and a high-density reinforcement, made up of steel rebar or tendons. Concrete structures in NPPs are often inaccessible and contain large volumes of massively thick concrete. While acoustic imaging using synthetic aperture focusing technique (SAFT) works adequately well for thin specimens of concrete such as concrete transportation structures, enhancements are needed for heavily reinforced, thick concrete.

We argue that image reconstruction quality for acoustic imaging in thick concrete could be improved with Model-Based Iterative Reconstruction (MBIR) techniques. MBIR is a powerful technique for solving inverse problems. MBIR works by designing a probabilistic model for the measurements (forward model) and a probabilistic model for the object (prior model). Both models are used to formulate an objective function (cost function), such as the maximum a posteriori (MAP) cost function. The final step in MBIR is to optimize the cost function. While more accurate models produce high quality solutions, they make the cost function more complicated. This in return makes solving the inverse problem very computationally expensive. For our application, MBIR will iterate until it finds the intensity reflectivity coefficients (IRC) for every voxel on the field of view that optimize the cost function. Previously, we have demonstrated a first implementation of MBIR for an ultrasonic transducer array system. The original forward model has been upgraded to account for direct arrival signal, which greatly contributes to reconstruction artifacts in particular for one-sided reconstruction. This upgrade is successfully able to cancel out the effect of the direct arrival signal on the reconstruction. Updates to the forward model will be documented and the new algorithm will be assessed with synthetic and empirical samples.

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