MAE Seminar SERIES

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THREE-DIMENSIONAL STOCHASTIC NUMERICAL BREAST PHANTOMS FOR ENABLING VIRTUAL IMAGING TRIALS OF ULTRASOUND AND PHOTOACOUSTIC COMPUTED TOMOGRAPHY

ABSTRACT

Ultrasound computed tomography (USCT) and photoacoustic computed tomography (PACT) are non-invasive, radiation-free, low-cost imaging modalities that could help identify new biomarkers for early detection of breast cancer, as well as monitoring response to treatment. USCT can measure intrinsic tumor properties quantitatively by estimating biophysical parameters, such as speed of sound, density and acoustic attenuation, and can produce high-resolution and high-contrast images of tissue acoustic properties. PACT combines endogenous hemoglobin contrast of optical imaging modalities (such as diffuse optical tomography) with ultrasound detection principles to produce high resolution images of concentration and oxygenation state of hemoglobin within tissue. PACT can thus assess tumor angiogenesis (the formation of new blood vessels structures) and hypoxia (a state of low oxygenation), which result from the increased metabolic activity of aggressively growing malignant breast tumors.

However, widespread application of these imaging modalities in a clinical setting requires further investigation. Computer-simulation studies, also known as virtual imaging trials, provide researchers with an economical and convenient route to systematically explore imaging system designs and image reconstruction methods. When simulating an imaging technology intended for clinical use, it is essential to employ realistic numerical phantoms that can facilitate the objective, or task-based, assessment of image quality. Moreover, when computing objective image quality measures, an ensemble of such phantoms should be employed that display the variability in anatomy and object properties that is representative of the to-be-imaged patient cohort. Such stochastic phantoms for clinically relevant applications of USCT and PACT are currently lacking.

In this talk, a methodology for producing realistic three-dimensional (3D) numerical breast phantoms for enabling clinically relevant computer-simulation studies of USCT and PACT breast imaging is presented. By extending and adapting an existing stochastic 3D breast phantom for use with USCT and PACT, methods for creating ensembles of numerical acoustic breast phantoms are established. These breast phantoms will possess clinically relevant variations in breast size, composition, functional, optical, and acoustic properties, tumor locations, and tissue textures. A few case studies will be presented to demonstrate the use of the proposed phantoms to address the development and evaluation of image reconstruction methods in USCT and PACT. This work is in collaboration with Prof. Mark Anastasio, Dr. Seonyeong Park, and Fu Li at the Computational Imaging Science Laboratory of the University of Illinois at Urbana-Champaign.

BIO SKETCH

Dr. Villa is a Research Assistant Professor of Electrical & Systems Engineering at the McKelvey School of Engineering at Washington University in St Louis. He received the B.S. and M.S. degrees in Mathematical Engineering from Politecnico di Milano, Milan, Italy in 2005 and 2007, and the Ph.D. degree in Mathematics from Emory University, Atlanta, GA in 2012. He completed his postdoctoral training at the Center for Applied Scientific Computing of Lawrence Livermore National Laboratory. Prior to joining Washington University in 2018, he was a Research Associate in the Center for Computational Geosciences and Optimization led by Dr. Ghattas at the Oden Institute for Computational Engineering of the University of Texas at Austin.

Dr. Villa's research interests lie in the computational and mathematical aspects of large-scale inverse problems, imaging science, and uncertainty quantification. A strong component of his work includes developing scalable efficient algorithms for integrating data (images, experimental measurements, or observations), mathematical models, and machine learning with applications to biomedical and engineering relevant problems.

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