University of Rochester
Department of Electrical and Computer Engineering

Real-time Monitoring and Control of Transcranial Therapy Using Dual-mode Ultrasound Arrays

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Wednesday, November 9th
12:00PM – 1:00PM
Computer Studies Building (CSB) 209

Abstract: The use of focused ultrasound (FUS) for precise targeting brain circuitry was demonstrated since the 1950s by William and Francis Fry and their coworkers at the University of Illinois. Both animal and human in vivo studies were performed by this and other groups that demonstrated the reliability of forming precise “trackless” lesions in targeted brain tissue for the treatment of neurological disorders such as Parkinson’s disease. However, all these treatments required craniotomy to avoid FUS beam distortions due to the skull. Furthermore, the lack of diagnostic image guidance with high specificity to FUS-tissue interactions reduced enthusiasm for this form of therapy in comparison to radiosurgery, which was proposed at the same time by Lars Leksell. The advent of diagnostic image guidance in the 1990s, especially MRI, have renewed interest in FUS as a modality for transcranial therapy for the treatment of neurological disorders. More recently, several groups have reported on the use of transcranial FUS (tFUS) for neuromodulation in small animals, nonhuman primates and humans. While the mechanisms behind ultrasound neuromodulation are not yet fully understood, these observations have resulted in increased interest in the use of this technology in brain research. In this talk, we describe a unique paradigm for image-guided tFUS using a dual-mode ultrasound array (DMUA) system developed at our laboratory. This system employs advanced software/hardware architecture to support real-time monitoring and control of FUS energy to the target tissue and other critical structures in the path of the therapeutic beam. The SW architecture employs a multi-stream multithreaded supporting advanced GPU-based beamforming with a pipelined image processing engine (PIPE) at imaging frame rates up to 1000 fps. The SW/HW architecture supports multichannel FPGA-controlled tFUS-imaging transmit sequences fully-synchronized with the FPGA-controlled data acquisition at up to 500 fps. With these capabilities, we were able to perform the first closed-loop control (CLC) of tFUS in the rat brain in vivo at these frame rates. Combined with the DMUA capabilities to refocus the tFUS beams in real time, the high-frame-rate CLC ushers a new era of delivering targeted transcranial therapies as a prescription, i.e. precise control of the power deposition in space and time with millisecond and sub-millimeter precision. Example in vitro and in vivo experimental results will be given to demonstrate the DMUA capabilities in real-time monitoring and control of tFUS with potential clinical applications. In addition, the engineering aspects of our DMUA system will be described with sufficient detail to illustrate the potential of the DMUA technology in image-guided noninvasive surgery using FUS. Finally, a brief overview of our ongoing research on optimal broadband refocusing of transcranial FUS in neuromodulation and imaging applications will be given.

Bio: Emad S Ebbini is a Professor of Electrical and Computer Engineering at the University of Minnesota Twin Cities. He received his BSc in Electrical Engineering Communications from the University of Jordan and his MS and PhD from the University of Illinois at Urbana-Champaign. His research interests include phased arrays, nonlinear signal and array processing with applications in biomedical ultrasound. He received the NSF Young Investigator Award for his work on new ultrasound phased arrays for imaging and therapy and the NIH FIRST Award for his work on noninvasive temperature imaging using pulse-echo diagnostic ultrasound. Prof. Ebbini was elected Fellow of IEEE “for contributions to ultrasound temperature imaging and dual-mode ultrasound.” He served as an associate editor and editorial board member for several journals and as a guest editor for three special issues on therapeutic ultrasound.

Pizza and soda provided.