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Making MRI Scans Quieter through Time-Reversal Acoustics and Active Noise Control

JUNE 20, 2019 BY ADMIN

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Noise from magnetic resonance imaging (MRI) equipment puts patients at risk for hearing damage. Active noise control (ANC) systems have been implemented inside the MRI’s bore to reduce perceived noise, but the equipment used cannot have magnetic material or the ANC system will interfere with the MRI machine’s imaging quality. These systems are also limited in size because of the MRI machine’s small bore. Our project was to determine the feasibility of using time-reversal (TR) acoustics to remotely focus a noise-canceling signal to a desired point in space (e.g. a patient’s ear inside an MRI machine) and see if significant noise reduction could be achieved at that point. Being a feasibility study, our experiments were conducted under ideal conditions to better determine what conditions must be satisfied to achieve the most noise reduction.

Figure 1 shows our basic experimental setup: Our experiments used two loudspeakers and a microphone. The noise loudspeaker generates a noise signal (simulating the MRI machine) that is recorded by the microphone in a room. This recorded noise signal is used to create a noise-canceling signal that uses TR to focus at the microphone’s location. This focused noise-canceling signal, or control signal, is then broadcast from the control loudspeaker and recorded at the microphone. Note that these signals are recorded individually, not simultaneously. For this project, we manually time-aligned the two signals making it as if they had arrived at the microphone at the same time, as well as adjusted the volume of the control signal to make it possible for maximum cancelation to occur. This allowed us to simulate if TR used for the delivery of ANC (ANC+TR) is even possible. Once these conditions are satisfied, we calculate the overall sound pressure level (OASPL) of the noise signal and compare it to the OASPL of the combined noise and control signal to determine if there is any noise reduction. This experiment was conducted in two rooms, a reverberation chamber and a laboratory room, each having different acoustic properties to determine if room conditions contribute to greater noise reductions.

Using noise signals from scanning sequences we obtained from Brigham Young University’s MRI facility, we obtained noise reductions for each sequence as shown in Fig. 2. These four signals were chosen for their differing characteristics that are also likely represented in other MRI scanning sequences. Our results in Fig. 2 show that ANC+TR can achieve noise reduction in both rooms, but the greatest reductions occurred in the laboratory room by as much as 18 dB re 20 μPa. This is a promising result as a room housing an MRI machine has more similar acoustic properties to the laboratory room than a reverberation chamber.

The purpose of this project was to see if TR could be used for ANC purposes in quieting MRI noise. Our results show, under ideal conditions, that using ANC+TR does have potential for being used to reduce the noise a patient would experience during an MRI scan by up to 18 dB re 20 μPa. The actual implementation of using ANC+TR in real time, however, is beyond the scope of this project. Future work implementing ANC+TR in real time would have to address that TR takes time to focus a signal to a given location, meaning the control loudspeaker has to broadcast the noise-canceling signal before the noise has even been generated. If this challenge can be addressed, the arrival of the noise-canceling signal has be time-aligned with the noise generated by the MRI machine reaching the patients ears, or else the noise will be amplified instead of canceled. The volume of the noise-canceling signal also needs to closely match the MRI’s noise for greater cancelation to occur. These were the primary conditions we simulated in our experiments, and if they could be replicated in real time, we expect noise reduction to be achieved.
Figure 1 – Photograph of the experimental setup in a reverberation chamber with a noise loudspeaker, control loudspeaker, and microphone.

Figure 2 – Comparison of different MRI scans and their corresponding OASPL noise reductions in rooms with different reverberation times.

FILED UNDER: COLLEGE OF PHYSICAL AND MATHEMATICAL SCIENCES, ORCA-2018, PHYSICS AND ASTRONOMY