Conversation with a Colleague: Jordan Cheer

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Meet Jordan Cheer

Jordan Cheer is the next acoustician in our "Sound Perspectives" series "Conversation with a Colleague" (see bit.ly/ATC-CWC for previous essays). Jordan is currently an associate professor in the Institute of Sound and Vibration Research (ISVR) at the University of Southampton, Southampton, United Kingdom. He received his BMus in music and sound recording from the University of Surrey, Surrey, United Kingdom, and his MSc in sound and vibration from the University of Southampton. He worked with the Signal Processing and Control Group in the ISVR for his PhD. We asked Jordan to give us his elevator pitch and then to elaborate on his inspirations, contributions, and hopes for the future.

Give your "elevator speech" about the thrust(s) of your scholarly work over your career.

In everyday life, we are exposed to examples of sounds that we want to hear, such as our favorite music playing on our hi-fi system, and noise that we don't want to hear, such as the aircraft flying over our homes. Throughout my career, my research has focused on both how we can reduce unwanted noise and vibration and enhance or manipulate wanted sound. Early in my research career, I focused on how active sound control systems could be used to reduce unwanted sound, such as the road noise inside a car, or to generate spatially focused zones of audio reproduction to allow the driver in a car to listen to different audio than the passengers. Although seemingly distinct technologies, both rely on the same physical principles and utilize loudspeakers to generate carefully designed sound fields via constructive and destructive interference. My research has since expanded to consider how similar active approaches can be used to control vibration in structures, often with the ultimate aim of controlling the sound field radiated by the structure. Although the active technologies that much of my research has focused on have significant performance advantages at low frequencies, physical limitations occur at higher frequencies. Therefore, over the last few years, I have also begun to explore how the active control systems can be effectively integrated with passive systems to augment performance and capabilities in various ways; this has seen my team explore the integration of active control systems into passive acoustic and vibration-based metamaterials and acoustic black holes, leading to the unifying concept of intelligent structures for low-noise environments.

What inspired you to work in this area of scholarship?

My interest in sound stems from my background as a musician, but my curiosity about the technical side of acoustics grew during my undergraduate studies on the Tonmeister program at the University of Surrey, which covers both music and sound recording. This led me to join the ISVR at the University of Southampton for a masters, during which I completed my dissertation under the supervision of Steve Elliott and began my research in the field of active sound control. Initially, I focused on the realization of directional loudspeakers for audio reproduction, remaining consistent with my background in audio, but as my understanding of sound field control increased, I developed an interest in how the same physical principles can be exploited to control noise. Under the supervision of Steve Elliott, my PhD focused on combining these two areas within the context of the automotive environment, exploring how active control

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can be used to reduce road noise, manipulate engine noise, and generate multiple independent listening zones within a car. This period of training in research under Steve's mentorship inspired my future research focus as well as my decision to pursue an academic career, where I have been motivated by being able to work in multiple industries including automotive, aerospace, maritime, and telecommunications.

Of all your contributions during your career, which are you most proud of and why?

In terms of research, I am probably most proud of my work on the active control of acoustic scattering. Having spent several years working on active sound field control with Steve Elliott at the ISVR during my PhD and first postdoctoral position, my work on the active control of acoustic scattering was my first work as an independent investigator. Around that time, there were several groups exploring the use of passive metamaterials for the control of acoustic scattering, with the aim of acoustically cloaking an object. My work, however, focused on the application of active strategies to control scattering.

This approach uses additional acoustic sources to generate a secondary field that is tuned to interfere with the unwanted primary sound field destructively, which in this case is the scattered field. Typically, active control strategies work well at low frequencies because the number of acoustic sources required to achieve control increases rapidly with frequency and so quickly becomes impractical. My initial research into active acoustic-scattering control, or active acoustic cloaking, explored how well-established insight into the physical limitations of active noise control and sound field reproduction could be used to build an understanding of the corresponding limitations for active acoustic cloaking.

This initial study into active acoustic cloaking was purely simulation based but provided a number of new insights that were critical in extending the work to practical applications. First, it provided a common framework for formulating the related sound field control problems of active noise control, sound field reproduction, and active scattering control. This common framework demonstrated that active acoustic cloaking is mathematically equivalent to actively canceling the primary sound field produced in the presence of the scattering object and then reproducing the primary sound field that would occur in the absence of the scattering object. However, more practically, and probably more intuitively, active cloaking must directly cancel the scattered component of the sound field.

Following the insight provided by the consistent formulation of the three sound field control problems, I used numerical simulations to investigate the physical limitations on active acoustic cloaking. In particular, the change in performance with frequency and both the number and position of the acoustic control sources were investigated. This highlighted the importance of locating the control sources close to the scattering object to maximize the control performance and also the frequency range over which effective cloaking could be achieved. Consistent with active control in general, increasing the number of control sources was shown to increase performance. However, from a practical perspective, it was interesting to show that relatively high levels of cloaking performance can be achieved with a relatively small number of acoustic control sources if they are located in close proximity to the scattering object.

The initial simulation-based study into active cloaking focused on the classical problem of scattering from a rigid sphere, but as a first step in taking the fundamental insights to a more practical application, the control strategies were also applied to the less straightforward problem of scattering from a rigid cuboid. These results showed similar physical limitations but also further highlighted the challenges to practically implementing an active acoustic cloak. This work consequently led to a number of follow-on research programs that focused on the experimental investigation of active acoustic cloaking, alternative active control strategies, combined passive-active cloaking strategies, various approaches to actuating control, and approaches to sensing the scattered acoustic field using remote-sensing techniques. As always, this subsequent research has probably raised more questions than it answered, but for me, finding out what you don't know is one of the most motivating things about research.

What are some of the other areas in which you feel you made substantive contributions over your career?

During my PhD, I was financially supported to work on active noise control for green city cars. However, my background and personal interest in audio systems led me to explore how similar sound field control techniques could be used in the automotive environment. This led to the investigation of how we can generate independent listening zones in a car cabin that allow, for example, the driver to listen to navigation while the rear seat passengers listen to music without disturbing each other. We developed the first system, at least publicly, that was able to generate independent listening zones in the front and rear of a car cabin, and this relied on a combination of headrest-mounted loudspeakers operating at high frequencies and the standard door-mounted car audio loudspeakers at low frequencies. The low-frequency performance relied on active sound field control approaches while the high-frequency performance relied on the proximity and directivity of the headrest-mounted loudspeakers. Although the performance of the system was some way from commercial exploitation, it seemed either to be quite timely or to motivate many other researchers and companies to explore the potential of in-car zonal audio.

More recently, I have become involved in research into acoustic black holes. The concept of acoustic black holes was established quite some time ago and generally relies on tapering the thickness profile of a structure to reduce the structural wave speed. The decrease in wave speed massively enhances the effect of damping treatments, and acoustic black holes thus provide a very weight efficient vibration control treatment. However, this only works well at frequencies above some cut-on frequency, but the performance is limited at lower frequencies. This limitation led my group to explore and make some useful contributions to the concept of active acoustic black holes. Our research in this area has demonstrated how combining the active and passive concepts into the acoustic black hole design can broaden the frequency range over which they can provide effective vibration control but also reduces the electrical and computational power requirements compared with straightforward active vibration control. This approach thus provides a very high level of vibration control performance and, in fact, reduces the weight of the structure.

Outside of my research contributions, I am extremely proud of my contributions to the supervision of graduate students. Helping to support and encourage their development is extremely rewarding, and helping them to fulfill their potential beyond their PhD studies feels like the most effective way of creating impact from my work.

What do you think are the most pressing open questions that you would like to focus on over the next 5-10 years?

Active control of noise and sound field control for audio reproduction are now both relatively well-established technologies. However, what is perhaps less well-established is how the two technologies interact from a subjective perspective and how they should be optimized in combination to best improve user experience in various scenarios. I find this challenge particularly interesting because it requires an understanding of active sound control to come together with psychoacoustics, user experience, and, most likely, some form of artificial intelligence. Therefore, there is not only the opportunity to make interesting contributions to the field but also to learn and collaborate more widely, which I find particularly motivating.

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