

Digital Preservation and Access to Aural Heritage Via a Scalable, Extensible Method

NEH Research and Development Preservation and Access

*Digital Preservation and Access to Aural Heritage
Via a Scalable, Extensible Method*

(2019-2022)

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1. Project Summary

Aural heritage research documents, reconstructs, and preserves the sonic interactivity of sites important to humans across time and around the world.

Project co-organizers Kim, Ko, and Kolar proposed and developed a methodology for aural heritage preservation and access based on our working definition of aural heritage: “spatial acoustics as physically experienced by humans in cultural contexts” (Kolar et al. 2021).

This project was formed to develop, test, and share aural heritage preservation, translation, and access technologies via three detailed case studies and associated outreach, including publications and demonstrations.

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We proposed and produced the following during this project:

1) a translatable aural heritage data (acoustics + culturally contextualized auditory perspective) collection protocol for long-term preservation and virtual representations of this intangible form of cultural heritage — detailed in research publications (conference presentations and articles) that document our case-study activities and provide technical procedures;

2) a method for processing aural heritage data into scalable auralizations (reconstructions for listening) to translate across audio reproduction platforms of different sizes and configurations — detailed in research publications (conference presentations and articles) that document our case-study activities and provide technical procedures, with auralization examples featured on the project website;

3) tutorials and extensibility pathways for other researchers to implement these methodologies, including workshop and demonstration events, web-based tutorials, and other publicly accessible project products and resources — our project website lists the public and scholarly events we produced, provides links to scholarly articles to inform other researchers, and makes available tutorials for non-specialists.

Project resources are available through our project website:

<http://www.auralheritage.org/>

with case-study aural heritage data (acoustical impulse responses and other forms of site-specific documentation) archived in the Belmont University Library's digital repository:

<https://repository.belmont.edu/auralheritage/>.

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2. Project Origins and Goals

This project was formed to develop, through case-study research, an aural heritage data collection, preservation, and access protocol extensible across distinct and contrasting cultural heritage contexts. Our three case-study sites present socio-temporal and architectural contrasts: 1) Columbia Studio A, a classic American recording studio on Nashville's Music Row; 2) the Rochester Savings Bank, an ornate Byzantine-revival historical building from the early 20th century in upstate New York that is on the National Register of Historic Places, and 3) the 3,000-year-old, Pre-Columbian architecture of the UNESCO World Heritage archaeological site at Chavín de Huántar, Peru.



Aural Heritage data collection and equipment comparison studies in modern case-study sites; left: (2019) Columbia Studio A, on Nashville's Music Row; right: (2020) in the Byzantine-revival main room of the Rochester Savings Bank in downtown Rochester, New York, no longer in use as a bank, and listed on the National Register of Historic Places. Note the variety of equipment and the multiple source (loudspeaker) and receiver (microphone) placements, according to both room acoustics standards and human-centered cultural-use scenarios. We documented acoustical data collection in our three case-study sites visually, with 360-degree photography. We used standard binaural and multichannel measurement techniques plus new microphone arrangements to enable perceptual comparisons in laboratory auralization experiments.

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Aural Heritage case-study data collection in fieldwork at the UNESCO World Heritage archaeological site Chavín de Huántar, Peru (2019) in the recently excavated area known as the Explanada Gallery (photos © Kolar/Programa de Investigación Arqueológica y Conservación Chavín de Huántar 2019); note the binaurally spaced microphones as proxies for the ears of a human listener (left) as well as the use of an Ambisonics microphone paired with a 360-degree camera (right) for congruent auditory-visual data collection with sound from a directional loudspeaker that approximates the acoustical features of a human voice for ecological validity (realism).

The three project organizers (Co-PI's Sungyoung Kim and Doyuen Ko, and Consultant Miriam Kolar) have extensive experience in measuring room acoustics and translating them virtually through audio engineering techniques (e.g., Ko 2009 & 2016; Kim 2017; Kolar et al. 2018). Importantly, this project moves beyond research practices and acoustical measurement standards that are based on the specifics of western architecture and art music, to address the diverse architectural and cultural-use features of a wider range of cultural heritage contexts, with attention to human perception. Therefore, we aimed to develop a cross-culturally and cross-temporally extensible methodology, and so, we sought to define and address concerns pertinent to documenting and preserving aural heritage across time and geography. This research approach is particularly aligned the consultant's archaeological acoustics research (Kolar 2013). At the same time, the Co-PI's background in the virtual translation of spatial acoustics for musical performers and audiences (Kim et al. 2013; Ko et al. 2018) requires a focus on the human perception of acoustics that is fundamental to our technical explorations for aural heritage

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documentation and demonstration. The three co-organizers' backgrounds and research interests were complementary in addressing the human perceptual and socio-cultural concerns that informed our project's new approach to spatial acoustics for aural heritage preservation and access.

Two factors distinguish aural heritage data collection from standard room acoustics practice: attention to 1) cultural contextualization and 2) human perceptual experience. Doing so requires that knowledge about the socio-cultural factors that inform both how a space has been used, by whom, and under what conditions. Cultural-use scenarios must be reflected in the aural heritage research design, informing the human perspectives that are proxied by the microphones that receive sound and the measurement sound source locations in data collection processes. Research design according to these anthropological frameworks ensures ecological validity (realism) with respect to cultural heritage concerns. Further, to translate aural heritage data into auralization experiences that demonstrate it virtually, human perception of virtual acoustics technologies, rendering methods, and immersion contexts must be studied.

Therefore, as a starting premise, aural heritage documentation (contextualized data collection) and reconstruction (auralization) should be informed by contextual knowledge of both present-day situations as well as past scenarios suggested by historical records or archaeological materials. The distinct cultural contexts of our case-study sites enabled us to test a methodology for extensibility as well as site-specific utility. Also, the logistical differences across case-study sites could be taken into consideration, along with the backgrounds of site constituencies in terms of providing access. Our data collection focus on fieldwork methodologies was therefore paired with perceptual testing of aural heritage auralizations through different audio systems.

This project sought to bring to attention the overlooked possibilities and importance of aural heritage to Humanities scholars, the cultural heritage

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community, and broader audiences. Our team's demonstrated cross-disciplinary expertise, supported by an Advisory Board of experts from different communities with whom we held virtual meetings, helped us to address the concerns of practitioners in distinct fields.

We are especially concerned with serving the cultural heritage preservation community, and thus our project seeks to provide new tools for cultural heritage practitioners, including historians of music and architecture, and those who might adopt the protocol in their work, such as archaeologists, audio engineers, musicians, artists, and virtual media practitioners. We have prioritized research outputs that facilitate the use of specialized technologies by non-specialists; therefore, we created a site website to centralize project dissemination, and we programmed events across disciplines, and in public contexts.

3. Project Activities, Team, & Participants

Research activities involved the core team of organizers, students, visiting scholars, and case-study cultural heritage site community members.

All stages of the aural heritage protocol development were shared with researchers and public audiences, via presentations, workshops, aural heritage auralization demonstrations and published articles.

Dissemination event highlights include our hosting a virtual panel discussion on cultural heritage acoustics at Acoustics In Focus (2021) and an in-person aural heritage virtual acoustics auralization demonstration at the Nashville Meeting of the Acoustical Society of America (2022). For a Humanities scholarly audience, we presented an aural heritage workshop as an Amherst College Center for Humanistic Inquiry (CHI) Salon (2021). We presented technical details of our work as conference papers and posters at the 151st convention of the Audio Engineering Society (AES, 2021) and at the 24th

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International Conference on Acoustics (ICA, 2022). For the general public, we hosted a full day of demonstrations about aural heritage, with immersive auralization demonstrations, at the Imagine RIT creativity and innovation festival (2022). RIT has a research group on “cultural heritage imaging, preservation, and research” (CHIPR) and it held a conference in which we demonstrated immersive auralizations for New York state Humanities researchers (2022). We published several peer-reviewed and Open Access conference and journal publications that detail technical aspects of our research, linked on our project website as free downloads.

To make aural heritage viable across knowledge domains, we have concentrated on the production of conceptual guidelines with technical specificity that detail considerations and procedures for the inclusion of aural heritage in the projects of Humanities researchers and among the activities of cultural heritage preservationists, among other targeted constituencies. Multiple channels of dissemination and outreach, enumerated and linked on our website, widen the accessibility of the specialized research methodologies that we have developed. We planned and conducted several workshops and demonstration events — for Humanities researchers, acousticians and audio engineers, and the general public, and we have created several web-based tutorials, and other forms of documentation that guide the adoption of the aural heritage protocol.

During the four years of this project, the Co-PI’s and Consultant worked consistently beyond the budgeted person-months on research, project administration, mentoring, public interface development, publications, and other research dissemination activities. Several students and visiting researchers were mentored and financially supported; fieldwork in the case-study sites brought a larger set of aural heritage constituencies into conversation, including site support staff, historians, archaeologists, and local community members. We held two meetings with our multidisciplinary Advisory Board, whose members were: George Massenburg, recording engineer and producer (Member of National Recording Preservation Board,

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Advisor of the Committee for Library Information Resources, Library of Congress); Patrick A. McMakin, recording engineer and music producer (Director of Operations, Ocean Way Studio, Nashville, founding board member of the Music Row Neighborhood Association); Hideo Miyazaki, acoustical consultant (manager of the acoustic design and consulting group of Yamaha Corporation); John Rick, archaeologist (Associate Professor, Dept. of Anthropology at Stanford University); and Michael E. Ruhling, musicologist (Professor of Performing Arts in the College of Liberal Arts at RIT, and a Senior Associate Faculty in Musicology at the Eastman School of Music).

Whereas the Covid-19 pandemic interrupted planned activities, we were able to continue research remotely, convene meetings and conference events via Zoom, and extend the initially 3-year project for a 4th, no-cost extension year, which, in 2022, enabled us to gather again as a team, hold in-person public events, and attend conferences in person as initially planned.

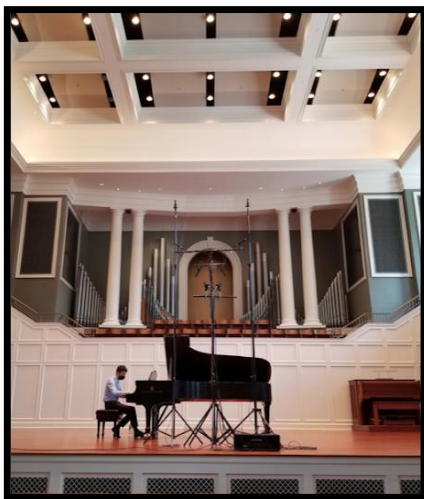
During the no-cost extension year (2022), the three co-organizers extended testing of the aural heritage protocol beyond the contrasting case-study sites, to further verify the expandability of its temporal and topical applicability. The Co-PI's, audio engineers who focus on music applications, conducted fieldwork in the McAfee contemporary concert hall at Belmont University, with follow-up perceptual verification experiments, to convey an optimal experience of listening to solo piano music in a Western classical music concert setting (Lu et al. 2022). The Consultant, an archaeoacoustician, tested the protocol during archaeological fieldwork in an additional UNESCO World Heritage site, in south-central France, to document and preserve physically possible human perspectives on the undisturbed Upper Paleolithic art context of Chauvet Cave (36,000 years before present) (Kolar et al. 2022).

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Additional testing of the aural heritage data collection protocol in Chauvet Cave (Ardèche, France; photos © Kolar/Équipe Chauvet 2022), where two first-order Ambisonics microphone arrays are used in binaural configuration as proxy for a human listener; right photo shows cultural-use scenario of source and receiver near the bear painting in the Cactus Gallery.



Additional testing of the aural heritage data collection protocol in the McAfee Concert Hall of Belmont University (left) in Nashville (TN, USA), where the W-Ambisonics multi-microphone array (Lu et al. 2021) developed in this project was used for data collection (left); shown with its virtual translation in RIT's immersive media laboratory (right) for perceptual evaluations of aural heritage rendering with congruent visual stimuli (Lu et al. 2022). In the laboratory, the binaural mannequin is shown in the place of an experiment participant, enabling data comparison.

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Perceptual evaluations of both collected aural heritage data and its translation in various auralization renderings completed our testing of a protocol that starts with contextualized data collection, and ends with virtual reality demonstrations. We learned, as expected, more about the ways that virtualization technologies play a strong role in the perception of attributes of the data, and that multisensory perception is a pivotal consideration for immersive media representations of aural heritage data (Lu et al. 2022). Though our focus for the project was aural heritage alone, at the end of the project, we recommend continued research that operationalizes aural heritage in multisensory context.

4. Project Outcomes

We conducted case-study research that enabled us to advance methodologically on project goals, while simultaneously introducing aural heritage concerns to others through collaborative participation. During fieldwork and in laboratory research, the project involved students, visiting researchers, colleagues in the scholarly and audio engineering communities, colleagues in the archaeological research community, as well as historical and archaeological site constituents. Scholarly and public presentations made our work known to a broad audience, further addressed by our project website, with resources from introductory tutorials for non-specialists, to links to technical papers that we have published in peer-reviewed journals, and presented at professional conferences.

Through the many project events and products, addressed to different constituent communities and audiences, our project has contributed to the expansion of aural heritage explorations, both within and beyond the disciplinary communities of the co-organizers. A related outcome is the consideration of our three case-study projects as augmented and virtual reality applications in cultural heritage; NEH funding was matched by RIT to

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support the expansion of a multimedia laboratory focused on perceptual experimentation, and we published several papers on relevant topics.

Into the future, our project website (<http://www.auralheritage.org/>) and the digital repositories of aural heritage data (acoustical impulse responses and contextual documentation of the site and data collection procedure) we produced that are archived with free public access by the Belmont University Library system (<https://repository.belmont.edu/auralheritage/>) will allow people to transcend the experience of locale through virtual aural heritage.

5. Project Evaluation and Impact

Developing our digital aural heritage research, preservation, and access protocol via consecutive case studies enabled us to evaluate our initial assumptions and refine our methodology between fieldwork and laboratory development, then back to the field, with interspersed presentations and community interactions, to share the work-in-progress with those outside our team. Monthly meetings among the three co-organizers enabled us to collaboratively advance on project goals. The project structure and timeline that we designed required that we develop our research iteratively, with opportunities for feedback from colleagues as part of our regular and ongoing participation in conferences, presentations, and conversations with our Advisory Board. Presentations to scholarly and public audiences also provided feedback from diverse constituencies that we took into consideration as we progressed through the case-studies, produced documentation on our research, and further tested the protocol in two additional and unplanned case-study cultural heritage sites.

Fieldwork in the first case study (Columbia Studio A, on Nashville's Music Row) enabled us to identify ways that aural heritage data collection is similar to standard room acoustics measurement, and also the new concerns raised by the specific purposes of this measurement and documentation fieldwork.

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In contrast, fieldwork in the second case study (the ornate, Byzantine-revival main room of the Rochester Savings Bank, in downtown Rochester, New York, listed on the National Register of Historic Places) required that we expand our knowledge of site socio-historical context, in part through conversations and material shared by the site caretaker, and that we explore spatial acoustical concerns that would not be pertinent to a site designed for music-making. Both the first and second case-study sites incorporated planning and participation of students and visiting researchers. The third case-study of interior architecture at the UNESCO World Heritage archaeological site Chavín de Huántar, Peru, was in contrast not a modern building, and presented logistical challenges common to work in remote archaeological sites. Archaeological community constituencies — archaeologists and local people involved in fieldwork — supported and observed the aural heritage fieldwork, broadening our impact to then international engagement of cultural heritage professionals and constituencies.

How to meaningfully evaluate the impact of our project on individuals, organizations, and the different fields to which it contributes is an ongoing concern. Whereas we have involved in this research people new to acoustical and audio engineering and/or to cultural heritage work — and incorporated their feedback in the development of the aural heritage protocol — we have not yet created surveys to produce any quantifiable or formalized evaluations of how our project has impacted their own work. One future idea for evaluation that we are considering in continuation of this project is to create web interfaces that request visitor feedback; note that our website visitor statistics in April 2023 logged around 2,500 page views per week on AuralHeritage.org, a resource that enables us to track tutorial usage, among other project products. Volunteers who have participated in perceptual research for our project have offered informal feedback, in addition to the controlled data produced about their experiences through our perceptual research (Lu et al. 2022). Follow-up correspondence initiated by colleagues/attendees of our presentations and events have been numerous,

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which demonstrates an impact on discourse within our specific scholarly and cultural heritage communities.

Some external measures of impact are available beyond project website statistics, for example readership/download metrics on some of our published articles: as of April 2023, our 2021 Open Access article “Preserving Human Perspectives in Cultural Heritage Acoustics: Distance Cues and Proxemics in Aural Heritage Fieldwork” (*Acoustics* Vol.3, No.1, pp.156-176) has received nearly 3,000 views on the journal’s website (<https://doi.org/10.3390/acoustics3010012>).

6. Project Continuation and Long-Term Impact

We expect to continue applications and refinement of the digital aural heritage protocol, and to make updates to our project website that reflect these advances. This project provided a strong foundation for the future endeavors of each of the co-organizers, as well as research experience and publication background for the 2 Belmont University students, 3 RIT students, and 3 Visiting Researchers at RIT who received support and made significant contributions to research, publications, and public presentations. Two student researchers in particular are continuing work as a result of their involvement in the project, that advances our goals in new directions: RIT student Jacob Cozzarin is near completion of a MS thesis in Computer Science entitled “Acoustical Preservation of Culturally Endangered Sites Utilizing an Accessible Means of Measuring Impulse Responses,” for which he has developed a mobile app that will allow impulse responses to be collected and analyzed in aural heritage fieldwork, and evaluated via a user study. Cozzarin plans to make the app freely available to the public. RIT Visiting Researcher Akira Takeuchi — who helped refine the immersive auralization interfaces, and also provided musical demonstration of the immersive aural heritage reconstructions — has continued his work in aural heritage virtual

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reality as a PhD student at RIT, with plans to present on aural heritage demonstration at the 2023 Imagine RIT creativity and innovation festival.

We take seriously the responsibility to continue our work on cultural heritage technologies innovation, having proposed new definitions and methodologies for digital cultural heritage preservation and access (Kolar et al. 2021; Kolar et al. 2022). Our project has produced detailed methodological advances at the intersection of virtual and extended reality technologies with cultural heritage preservation and access. As we survey the state-of-the-art — and consider future projects — we are convinced that multimodality and multisensory engagement is the next step. To this end, in our perceptual experiments to test, verify, and provide metrics regarding auditory translations of data collection into auralizations, we included research design with congruent visual stimuli, and we worked with auditory-visual immersion in our experiential reconstructions of aural heritage data (Lu et al. 2022). Human perception integrates the senses; therefore, future methods will focus on the integration of aural and visual heritage, with the same research attention to contextual factors including listeners' socio-cultural backgrounds.

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