Sound Science: Marking Ten International Conferences on Auditory Display

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This special issue of *ACM Transactions on Applied Perception* is intended to commemorate the tenth International Conference on Auditory Display (ICAD) and to serve as an introduction and overview of the field of auditory displays. This paper discusses the goals of the issue and describes the paper selection process. The selected papers are also introduced, with their connections to each other, their place in ICAD, and their relevance to other fields briefly highlighted.

Categories and Subject Descriptors: A.0 [**General Literature**]: General—*Conference Proceedings*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Audio input/output*; H.5.1 [**Information Interfaces and Presentation**]: User Interfaces—*Auditory (non-speech) feedback*; H.5.5 [**Information Interfaces and Presentation**]: Sound and Music Computing

General Terms: Experimentation, Human Factors, Performance

Additional Key Words and Phrases: Auditory display, sonification, International Conference on Auditory Display (ICAD)

1. INTRODUCTION

Auditory Display refers the use of sound to display data, monitor systems, and enhance user interfaces. The field is deeply interdisciplinary and most successful research is conducted by individuals or teams with multidisciplinary backgrounds, including, for example, music, computer science, psychology, and engineering. The International Conference on Auditory Display (ICAD; www.icad.org) has become the one international meeting where researchers from all backgrounds can present and discuss their auditory display work with a welcoming, knowledgeable, and scientifically rigorous community. To commemorate the tenth ICAD conference (2004 in Sydney, Australia), the ICAD Board of Directors invited Gregory Kramer, the founder of ICAD and organizer of the first conference in 1992, to assemble a collection of papers to fill two needs in the field of auditory display: a historical record representative of the first ten ICADs and a reference work to serve as a broad-spectrum contact point into the field. Kramer quickly invited Bruce Walker to join him as co-editor. Together, they proposed to the Board a paper selection process that clearly reflected the collection's purposes. It included a public call for

nominations from all of the ICAD conference papers, a collation by Kramer and Walker of these nominations, a presentation to the Board followed by Board nominations, and the assembly and subsequent Board approval of a final list assembled by the co-editors.

On the surface, the selection criteria were quite simple. The selected papers were to be of high quality, contributive to the field of Auditory Display, representative of ICAD as a whole, and include papers from every conference to date. These criteria initially produced a long list of nominations from the many excellent papers presented at ICAD between 1992 in Santa Fe, New Mexico and 2004 in Sydney, Australia. Because ICAD helped establish Auditory Display as a definable field and has served as the primary conference in this domain, these criteria alone set significant boundaries for the collection of papers. Simplifying the final selection process, we decided not to include any papers from the 1994 book *Auditory Display*, edited by Kramer, which was based on papers presented at the first ICAD in 1992. The editors and ICAD Board felt that those papers had already enjoyed wide exposure and it would be of greater service to the field to allot limited space in this journal issue to more recent works.

To ensure that the selection represented the broadest possible range of ICAD papers and research, a multivariate matrix was used to plot out the topics and categories into which each proposed paper fit. The many generations of spreadsheets produced during the selection process, and their copious headings, were quite enlightening as they provided sense of the strongly multidisciplinary nature of ICAD. Organizing headers included, for example, Application Areas (e.g., displays for blind users, general user interfaces, or seismic audifications); Disciplinary Emphasis (e.g., human factors, pedagogy, sound synthesis, or perceptual psychology); Associations (e.g., with music, aesthetics, or general design principles); and Technological Factors (e.g., association with immersive environments or a focus on tool building). Many papers cut across multiple headings, while others were highly focused in one or two areas.

One final criterion further focused this collection: it was decided that the author's body of work in auditory display would also be taken into account. This decision was made in the belief that papers drawn from a larger body of work would help make this collection more representative of the field and, by way of the new introductory papers solicited for this volume, help this compilation serve as an indicator of and index into a substantial aggregate body of work. This decision also unfortunately meant that some excellent papers by authors without a larger body of work in auditory display were not selected.

As is inevitable in such an endeavor, after the final decisions were made, it was clear that there remain many more excellent papers, from many productive auditory display researchers, than could be included in this collection. These were not easy decisions for the editors and the ICAD Board to make, but we hope that, overall, the collection serves as a solid indicator of the status of the field and a useful resource for researchers in this area.

Individual research projects using non-speech audio to convey information date back to Sonar, Geiger counters, and auditory thermometers [see Kramer 1994; Kramer et al. 1999]. However, for decades, the field was very sparse, marked by quality work at disparate locations and research papers scattered across various journals. When ICAD was founded in 1992, the conference and associated community developed into a home for this research; from this emerged a more unified and continuous line of publication. Thus, to some extent, the history of ICAD is representative of the (recent) history of Auditory Display. However, to the extent that this is a historically representative collection, it must be stated that it is a highly truncated one. Many disciplines, application areas, design ideas, and other dynamic factors in the field are simply not represented here due to a variety of factors, including space and the selection criteria we employed. We are missing the seismic audifications and aesthetically powerful designs seen at some ICADs. We see little of the work done in the early days when supercomputers or parallel processing were strong factors at the conference. Even applications for blind users, evident

across many conferences, are only hinted at in the bodies of work by some contributing authors such as Walker, Edwards, and Flowers. For a fuller exploration of the field, the reader is referred to "Auditory Display: Sonification, Audification and Auditory Interfaces" [Kramer 1994, previously mentioned], the "Sonification Report: Status of the Field and Research Agenda" [Kramer et al. 1999], which was prepared for the National Science Foundation by members of the International Community for Auditory Display, and also the complete proceedings of the ICAD conferences (www.icad.org).

ICAD has been not only a forum for the presentation of scientific papers, but also a complex community that facilitates collaboration, supports innovative work, and somehow manages to, once each year, provide an atmosphere of fun, encouragement, and exhaustingly hard work. As an unaffiliated conference, it has remained flexible and creative in its form. A tone of creativity and tolerance is balanced with rigor and a consistently empirical emphasis. Established researchers and graduate students alike find support from the ICAD community; productive collaborations are regularly developed; and a single-track structure has, for years, helped generate cross-disciplinary learning. ICAD has evolved to include traditional paper presentations, concerts, tutorials and workshops, community building activities, special sessions and symposia, lab tours, media events, and graduate student "ThinkTanks."

Over these first 12 years (1992–2004) the field has moved beyond questioning if auditory displays can be useful and on to the richer questions of how can they be made useful, when and where should they be applied, and what can we learn about the human perceptual system by way of these complex, but manipulable, displays. At early ICAD conferences there was often talk of the frustrations people experienced trying to do their work. There was, we consistently heard, a lack of sound-producing hardware and software suitable for realizing their experimental systems. Researchers encountered resistance from colleagues who had no notion of what auditory displays were and unconsidered opinions that such displays simply would not be of any use: "Why not just use a graphical display?" was a typical a response, as was, "I'm sorry, but our computer system has no audio capability, and anyway, our lab has no speakers." Thankfully, and certainly due to the hard work of many active members of this research field, those days are largely behind us and an interesting future of auditory display lies ahead. There are still hurdles, but hardware and software impediments are relatively minor. Now it remains for us, as a field, and as a community, to carry on with the tough questions of how to "get it right" with this display modality. The papers in this collection give some indication of the past and ongoing work that is being done with exactly this goal in mind.

2.   THE PAPERS

The fourteen ICAD conference papers that were selected for inclusion have been reprinted in their original form, reformatted to match the journal style, and are presented with only minor corrections and updates to outdated references. The intention is to maintain the original character of the paper and preserve the historical aspect of the compilation. In some cases, the original papers have been supplemented with data and results that were part of the actual ICAD presentation, but were not available in time for the proceedings deadline for that conference. Those additions appear as an appendix to the original paper. The papers are ordered chronologically, starting with the 1994 paper by Stephen Barrass and concluding with the 2004 paper by Kees van den Doel.

In addition, the authors were asked to provide a brief supplementary article to introduce their original paper and to set it into context. They comment on why and how they became involved in the field of Auditory Display and what challenges they faced in doing this work. In addition, the authors show how this paper fits into their larger body of work and how that ties into the field as a whole. They often point to related work by other researchers, many of whom are not directly represented here. As a result, the whole collection, including the introductory papers by the authors, gives a nice connection to the roots

of this field as well as a solid link to the more recent and cutting-edge efforts that go well beyond the scope of any one paper included here.

It is interesting to see how the research presented in these papers is interconnected. Many threads of continuity can be discerned in this work despite (or perhaps because of) its interdisciplinary nature. The first two papers in this volume, Barrass [1994] and Walker and Kramer [1996], address the high-level question of fundamental design principles for auditory displays. While many of the papers in this volume address design issues, these two papers represent a growing body of work by these authors, and many others, focused on how auditory displays can conform well to human perception (e.g., a perceptually coherent display space) and cognition (e.g., the role of metaphor in display design). The [2001] paper by Shinn-Cunningham, Streeter, and Gyss also contributes to the discussion of display design by addressing low-level perceptual phenomena—plasticity in spatial hearing. There are several conferences and workshops dedicated specifically to spatial hearing, but this paper is emblematic of ICAD in that the focus is not on the perceptual phenomena in and of themselves, but on how and why these phenomena should be taken into account in display design. Similarly, the [2003] Brungart and Simpson paper is centered around research on spatial hearing but with an emphasis on a particular application: multi-talker speech displays. The usual focus at ICAD is on *non*-speech displays, but papers such as this offer design solutions relevant to a wide variety of displays by offering a principled approach to how spatialization can be employed.

Mitsopolous and Edwards' [1998] paper presents a different approach to principled design. It considers the conceptual, structural, and implementation issues of designing nonvisual interfaces, as exemplified by the creation of a listbox widget. This type of work, which might also be found at conferences focusing on human–computer interaction (e.g., ACM CHI; HCI), addresses a specific technique that can be applied to a wide variety of applications within a computer interface. In this, it shares much with the [1997] paper by Brewster and Clark in which broadly applicable sonically enhanced palettes are evaluated for use in any kind of computer application. The [1996] paper by Flowers, Buhman, and Turnage uses the challenge of sonification of spreadsheets as a platform for discussing the utility of providing auditory display tools in a variety of common desktop applications. Auditory graphs and sonified spreadsheets are now regularly addressed at ICAD.

In contrast to broad themes or application possibilities, some papers have focused on one specific application area. The particular application outlined by Vickers and Alty in their [2000] paper is the auditory display of computer program execution, which has generated considerable interest in the computing and programming education fields. This paper is reminiscent of not only the authors' body of work in this area but of early ICAD conferences, where auditory indicators of program execution on platforms ranging from PCs to supercomputers were a common theme. This is, in a broader sense, representative of many successful auditory displays that are effective in process monitoring, pattern detection, and eyes-busy information display. Another application that has seen several approaches at ICAD is browsing through volumes of data, such as libraries of media clips. As a fine representative of this area, Fernstrom and McNamara's [1998] paper investigates the utility of using sound to support browsing (what they call "interactive sonification"). They demonstrate the benefit of using multiple streams of sound to support the task and point out that this kind of auditory enhancement could be applied to many types of human–computer interfaces.

Most of the papers presented at ICAD involve evaluations of the display methodologies, tools, or design principles being proffered. The [1998] paper by Bonebright, Miner, Goldsmith, and Caudell reviews a variety of data collection and analysis techniques and is representative of the overview papers that appear at ICAD from time to time. When a conference is populated by computer scientists, psychologists, composers, design theorists, applications experts, and others, papers like this educate the community and help provide a common language for presenting research results.

Providing the basic tools for building auditory displays is another common theme across all ten ICADs. Miner and Caudell's [1997] paper and van den Doel's [2004] paper both offer sound synthesis algorithms that can be flexibly applied to displays where realistic or suggestive sounds are needed, such as immersive virtual environments. Indeed, papers like this have connections to similar work presented at conferences focused on virtual environments and even video game or film sound and computer music. Hermann and Ritter's [2002] paper offers not only a set of tools, but a novel sonification design approach made possible by purpose-designed sound and data-rendering software. These implementation approaches also tie back into, and in many ways complement, the previously discussed papers that address design, perception, human–computer interaction, and evaluation of auditory displays. The [2003] paper by Gröhn, Lokki, and Takala is an excellent example of a multidisciplinary team addressing many of the issues present at ICAD. The authors' team developed the software and hardware used to render the display, addressed basic perception and human factors issues in the display design and described a complex task that was evaluated using human subjects. The elements of this paper could have been presented at any number of conferences, including computer science, engineering, human factors, and virtual environments. Needless to say, it was a good fit at ICAD.

The kinds of questions asked at ICAD, the approaches taken, and the methods used have evolved over the years. Also, the interests of the research community change with time and technology. Some application areas have virtually disappeared, such as those having to do with supercomputing. In past years, a great deal of work was presented on auditory icons, earcons, and widgets; ICAD now sees less in this area. Some ICAD conferences see a profusion of research on low-level auditory perception, while others have been more focused on aesthetics and design. These kinds of changes will continue to manifest as the field matures and evolves, along with the research world as a whole.

In a conference that covers as many disciplines as ICAD, the question is always alive as to what is or is not appropriate for the conference. There is, however, the thread that holds together all of these conferences, papers, and the people who attend them: a direct relationship between the work and auditory displays per se. We hope that this collection lives up to its purpose of presenting the multifaceted work of this community. We hope this volume proves helpful both for those who work in this area and those who have limited or no previous exposure to the use of sound to display information.

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