

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re *Inter Partes* Review of:)
U.S. Patent No. 11,290,836)
Issued: March 29, 2022)
Application No.: 18/062,637)
Filing Date: October 5, 2020)

For: **Providing Binaural Sound Behind an Image Being Displayed With An
Electronic Device**

FILED VIA E2E

DECLARATION OF INGRID HSIEH-YEE, PH.D.

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I. Introduction

I, Ingrid Hsieh-Yee, Ph.D., do hereby declare as follows:

1. I have personal knowledge of all of the matters about which I testify in this declaration.

2. I have been retained as an independent expert witness on behalf of Meta Platforms, Inc. (“Meta”) for proceedings before the United States Patent and Trademark Office (“PTO”) regarding the authenticity and public availability of certain prior art references in relation to U.S. Patent No. 11,290,836 (“the ’836 patent,” **Ex. 1001**).

3. I am being compensated for my work in this matter at my customary hourly rate. I am also being reimbursed for any reasonable expenses associated with my work and testimony in this investigation. My compensation is not contingent on the results of my study, the substance of my opinions, or the outcome of this matter.

A. Qualifications and Professional Experience

4. My complete qualifications and professional experience are described in my academic *curriculum vitae* (**Ex. 1013**). The following is a brief summary of my relevant qualifications and professional experience.

5. In 2022, I was conferred the title of Professor Emerita after 32 years as a professor in the Department of Library and Information Science at the Catholic University of America. I have experience working in an academic library, a medical

library, and a legislative library. I hold a Ph.D. in Library and Information Studies from the University of Wisconsin-Madison and a Masters in Library and Information Studies from the University of Wisconsin-Madison.

6. I am an expert on library cataloging and classification and have published two editions on this subject, *Organizing Audiovisual and Electronic Resources for Access: A Cataloging Guide* (2000 and 2006). I taught a variety of courses, including Cataloging and Classification, Advanced Cataloging and Classification, Organization of Internet Resources, Organization of Information, Metadata, Digital Content Creation and Management, Internet Searches and Web Design, Information Literacy Instruction, Advanced Information Retrieval and Analysis Strategies, and The Information Professions in Society. I am familiar with metadata schema design and implementation. In my teaching, I covered the design and implementation of metadata in databases, search engines, digital repositories, digital libraries, and digital archives. I also covered how information organization affects the discovery and access to digital resources on the Internet. My research interests cover cataloging and classification, information organization, metadata, information retrieval, information architecture, digital collections, scholarly communication, social media, user interaction with information systems, and others.

7. I am very familiar with a library cataloging encoding standard known as the “Machine-Readable Cataloging” standard, also known as “MARC,” which

became the national standard for sharing bibliographic data in the United States by 1971 and the international standard by 1973. I am also personally familiar with the Online Computer Library Center (OCLC), which is the largest bibliographic network of the world, with more than 554 million records and thousands of member institutions (many of which are libraries of some type) in more than 100 countries. I am also personally familiar with WorldCat (<http://www.worldcat.org>), which is a free web portal for users to explore more than 10,000 libraries worldwide. I provide a brief overview of MARC records, OCLC, WorldCat, and cataloging below at Section I.E.

8. I am also personally familiar with many online catalogs, databases, and search engines. In preparing for this declaration, I used the following authoritative information systems to search for records:

- ACM Digital Library (<https://dl.acm.org/>)
- Catalog of US Government Publications (CGP)
(<https://catalog.gpo.gov/F?RN=431058606>)
- Google Scholar (<https://scholar.google.com>)
- IEEE Xplore Digital Library
(<https://ieeexplore.ieee.org/Xplore/home.jsp>)
- NASA Technical Reports Server (NTRS, <https://ntrs.nasa.gov/>)
- OCLC FirstSearch (<https://firstsearch.oclc.org/>)

- Online catalog of the Library of Congress (<https://catalog.loc.gov/>)
- Online catalog of the Linda Hall Library
(https://catalog.lindahall.org/discovery/search?vid=01LINDAHALL_I NST:LHL)
- Online catalog of the North Carolina State University Libraries
(<https://catalog.lib.ncsu.edu/>)
- Online catalog of the STAATS- UND
UNIVERSITÄTSBIBLIOTHEK CARL VON OSSIETZKY
(<https://kataloge.hh.gbv.de/LNG=DU/DB=1/>)
- Online catalog of the Stanford University Library
(<https://searchworks.stanford.edu/>)
- Online catalog of the University of Michigan Library
(<https://search.lib.umich.edu/catalog?library=All+libraries>)
- Online catalog of the US Naval Academy Library
(<https://www.usna.edu/Library/>)
- Public catalog of the US Copyright Office (<https://cocatalog.loc.gov/>)
- WorldCat (<https://www.worldcat.org>)

B. Scope of This Declaration

9. I have been asked to offer an opinion on the authenticity and public availability date of the following documents:

- Begault, Durand R., (2000, August), *3-D Sound for Virtual Reality and Multimedia*, NASA-TM-2000-209606, published by the National Aeronautics and Space Administration (NASA), **Ex. 1006** (“*Begault*”);
- Finnegan, D. J., O'Neill, E., & Proulx, M. J., (2016, May), “Compensating for distance compression in audiovisual virtual environments using incongruence,” in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pp. 200-212, **Ex. 1005** (“*Finnegan*”);
- Algazi, V. R., Duda, R. O., Thompson, D. M., & Avendano, C., (2001, October), “The cipic hrtf database,” in *Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics*, pp. 99-102, **Ex. 1008** (“*Algazi*”);
- Zhou, Z., Cheok, A. D., Yang, X., & Qiu, Y., (2004, October), “An experimental study on the role of software synthesized 3D sound in augmented reality environments,” *Interacting with Computers*, vol. 16, issue 5, pp. 989-1016, **Ex. 1011** (“*Zhou*”).

10. I am rendering my expert opinion on the authenticity of the documents referenced herein and on whether they were published. I will provide my opinion on when and how these documents were publicly disseminated or otherwise made publicly available to the extent that persons interested and ordinarily skilled in the subject matter or art, exercising reasonable diligence, could have located and retrieved these documents.

11. I am informed by counsel that an item is considered authentic if there is sufficient evidence to support a finding that the item is what it is claimed to be. I am also informed that authenticity can be established based on the contents of the documents themselves, such as the appearance, content, substance, internal patterns, protocols followed or other distinctive characteristics of the item.

12. I am informed by counsel that a given reference is “published” if it is publicly accessible upon a satisfactory showing that such a document has been disseminated or otherwise made publicly available to the extent that persons interested and ordinarily skilled in the subject matter or art could locate it exercising reasonable diligence and obtain the document. I have also been informed by counsel that materials available in a library constitute “printed publications” if they are cataloged and indexed according to general library practices and protocols that make the references available and accessible to members of the interested public.

13. I have been informed by counsel that the '836 patent was filed in the United States on October 5, 2020 and that it claims priority to a parent application filed on May 24, 2017. I have assessed public accessibility of the documents referenced below as of this claimed priority date.

C. Person of Ordinary Skill in the Art

14. I have been informed by counsel that the subject matter of this proceeding relates to virtual/augmented reality systems.

15. I have been informed by counsel that a person of ordinary skill in the art at the time of the inventions ("POSA") is a hypothetical person who is presumed to be familiar with the relevant field and its literature at the time of the inventions. This hypothetical person is also a person of ordinary creativity, capable of understanding the scientific principles and literature applicable to the pertinent field.

16. I am told by counsel that persons of ordinary skill in this subject matter or art in the 2017 timeframe would have had a Bachelor's degree in computer science/engineering, digital signal processing, spatial audio, or a related field, with coursework in computer programming or virtual/augmented reality, and at least two years of industry experience, or academic research experience, in virtual/augmented reality, audio engineering, or an equivalent. Additional education can compensate for less experience, and vice-versa.

17. It is my opinion that such a person would have been actively engaged in learning about the field, possibly through formal instruction through the bibliographic resources. By at least May 2017, such a person would have had access to a vast array of print and electronic resources, including at least the documents referenced below.

D. Evidence Considered in Forming My Opinions

18. In the preparation of this declaration, I have reviewed the documents referenced below and any other documents I reference herein, and each of these is a type of material that experts in my field would reasonably rely upon when forming their opinions:

- (1) NTRS metadata record for *Begault-2000*, available at <https://ntrs.nasa.gov/citations/20010044352> from the NASA Technical Reports Server, accessed and obtained on January 24, 2023, **Appendix 1006A**;
- (2) Bibliographic and MARC records for the microfiche version of *Begault-2000*, available at https://catalog.gpo.gov/F/?func=direct&doc_number=000547656&local_base=GPO01PUB from the Catalog of U.S Government Publications, accessed and obtained on January 24, 2023, **Appendix 1006B**;
- (3) Bibliographic and MARC records for the microfiche version of *Begault-2000*, available at <https://searchworks.stanford.edu/view/4702295> from the online

catalog of Stanford University Library, accessed and obtained on January 24, 2023, **Appendix 1006C**;

- (4) Bibliographic and MARC records for *Begault-1994* published by AP Professional in 1994, available at <https://lcn.loc.gov/94028168> from the online catalog of the Library of Congress, accessed and obtained on January 24, 2023, **Appendix 1006D**;
- (5) Copyright registration record for *Begault-1994* published by AP Professional in 1994, available at https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?v1=1&ti=1,1&Search%5FArg=Begault%2C%20Durand&Search%5FCode=NALL&CNT=25&PID=btFSBdi9JGlyuOTDnCQetE_g75Za&SEQ=20230124170624&SID=2 from the public catalog of the U.S. Copyright Office, accessed and obtained on January 24, 2023, **Appendix 1006E**;
- (6) Bibliographic and MARC records for *Begault-1994* published by AP Professional in 1994, available at https://usna.primo.exlibrisgroup.com/permalink/01USNA_INS_T/5rvora/alma991000609529706751 from the online catalog of the US Naval Academy Library, accessed and obtained on January 24, 2023, **Appendix 1006F**;
- (7) Bibliographic and MARC records for *Begault-1994* published by AP Professional in 1994, available at <https://searchworks.stanford.edu/view/3099834> from the online catalog of Stanford University Library, accessed and obtained on January 24, 2023, **Appendix 1006G**;

- (8) 1995 and 2001 Citations to *Begault-1994* published by AP Professional in 1994, obtained from Google Scholar, **Appendix 1006H**;
- (9) ACM Digital Library metadata record for *Finnegan*, available at <https://dl.acm.org/doi/abs/10.1145/2858036.2858065>, and front matter of the *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* that contains *Finnegan*, available at <https://dl.acm.org/action/showFmPdf?doi=10.1145%2F285806>, accessed and obtained on February 22 and 28, 2023, **Appendix 1005A**;
- (10) Record for *#chi4good CHI 2016 : San Jose, CA, USA, May 7 - 12 : proceedings : the 34th Annual CHI Conference on Human Factors in Computing Systems* that contains *Finnegan*, available at <https://www.worldcat.org/title/949884930> from WorldCat; a German library record for this conference proceedings, available at <https://kataloge.hh.gbv.de/DB=1/SET=1/TTL=1/CMD?ACT=SRCHA&IKT=1016&SRT=YOP&TRM=9781450333627> from the online catalog of STAATS- UND UNIVERSITÄTSBIBLIOTHEK CARL VON OSSIETZKY; and the OCLC FirstSearch record for this library record (subscription required for access to OCLC FirstSearch), **Appendix 1005B**;
- (11) IEEE metadata record for *Algazi*, available at <https://ieeexplore.ieee.org/abstract/document/969552> from the

IEEE Xplore Digital Library, accessed and obtained on February 22, 2023, **Appendix 1008A**;

(12) Library copy of *Algazi*, obtained from the Linda Hall Library, **Appendix 1008B**;

(13) Bibliographic and MARC records for *Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics* that contains *Algazi*, available at https://catalog.lindahall.org/permalink/01LINDAHALL_INST/19lda7s/alma993595233405961 from the online catalog of the Linda Hall Library, accessed and obtained on March 9, 2023, **Appendix 1008C**;

(14) Bibliographic and MARC records for *Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics* that contains *Algazi*, available at <https://catalog.lib.ncsu.edu/catalog/NCSU1530971> from the online catalog of the North Carolina State University Library, accessed and obtained on April 25, 2023, **Appendix 1008D**;

(15) Copyright registration record for *Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics*, available at https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?Search_Arg=Proceedings+of+the+2001+IEEE+Workshop+on+the+Applications+of+Signal+Processing+to+Audio+and+Acoustic&Search_Code=TALL&PID=CnSHsJc_2VImSpJqtQaBGB89P4_r&SEQ=20230504135156&CNT=25&HIST=1 from the public catalog of the US Copyright Office, accessed and obtained on March 1, 2023, **Appendix 1008E**;

- (16) Citations to *Algazi*, obtained from Google Scholar, **Appendix 1008F**;
- (17) IEEE metadata record for *Zhou*, available at <https://ieeexplore.ieee.org/document/8160489> from the IEEE Xplore Digital Library, accessed and obtained on January 13, 2023, **Appendix 1011A**;
- (18) Library of Congress copy of *Zhou*, obtained on January 13, 2023, **Appendix 1011B**;
- (19) Bibliographic and MARC records for *Interacting with Computers* that contains *Zhou*, available at <https://lccn.loc.gov/89658522/> from the online catalog of the Library of Congress, accessed and obtained on January 13, 2023, **Appendix 1011C**;
- (20) University of Michigan Library copy of *Zhou*, obtained on January 17, 2023, **Appendix 1011D**;
- (21) Bibliographic and MARC records for *Interacting with Computers* that contains *Zhou*, available at <https://search.lib.umich.edu/catalog/record/990024764370106381> from the online catalog of the University of Michigan Library, accessed and obtained on January 13, 2023, **Appendix 1011E**;
- (22) Citations to *Zhou*, obtained from Google Scholar, **Appendix 1011F**.

These records are identified and discussed in this declaration. Experts in the field would reasonably rely on the data described herein to form their opinions.

E. Overview of MARC Records, OCLC, WorldCat, and Cataloging

19. MARC is the primary communications protocol for the transfer and storage of bibliographic metadata in libraries. Experts in my field would reasonably rely upon MARC records when forming their opinions.

20. A MARC record consists of several fields, each of which contains specific data about the work. Each field is identified by a standardized, unique, three-digit code corresponding to the type of data that follows. **Appendix A** is a true and correct copy of Parts VII to X of “Understanding MARC Bibliographic: Machine-Readable Cataloging” (<http://www.loc.gov/marc/umb/um07to10.html>) from the Library of Congress. *Understanding MARC Bibliographic* was originally published by the Follett Software Co. and copyrighted in 1988. Editions in 1989, 1990, 1994, 1998, 2000, 2003 and 2009 include changes. The latest edition was copyrighted in 2009. This document explains commonly-used MARC fields. For example, the personal author of the work is recorded in Field 100, the title is recorded in Field 245, publisher information is recorded in Field 260, the physical volume and characteristics of a publication are recorded in Field 300, and topical subjects are recorded in Fields 650.

21. OCLC was founded in 1967 to promote and support library cooperation. According to the “Third Article, Amended Articles of Incorporation of OCLC Online Computer Library Center, Inc.,” OCLC was created “to establish, maintain

and operate a computerized library network and to promote the evolution of library use, of libraries themselves, and of librarianship, and to provide processes and products for the benefit of library users and libraries, including such objectives as increasing availability of library resources to individual library patrons and reducing the rate of rise of library per-unit costs, all for the fundamental public purpose of furthering ease of access to and use of the ever-expanding body of worldwide scientific, literary and educational knowledge and information” (source: <https://www.oclc.org/content/dam/oclc/membership/articles-of-incorporation.pdf>).

22. OCLC members can contribute original cataloging records in MARC to the system or derive cataloging records from existing records, an activity referred to as “copy cataloging.” When an OCLC participating institution acquires a work, it can create an original MARC record for the work in OCLC’s Connexion system (a system for catalogers to create and share MARC records), and the system will automatically generate a code for the date of record creation in the yymmdd format, and the creating library’s OCLC symbol is recorded in subfield “a” of the 040 field. Once the MARC record is in Connexion, it becomes available to other OCLC members for adoption to their local online catalogs (*i.e.*, copy cataloging).

23. After a MARC record is created in Connexion, it also becomes searchable and viewable on WorldCat, which is a free web portal for users to explore more than 10,000 libraries worldwide. Records in WorldCat, however, are not

presented in MARC fields. Instead, the data elements are labeled to help users interpret the records. Thus, the information stored in MARC records in Connexion is available to the interested public through the user-friendly WorldCat web portal.

24. WorldCat is “the world’s largest network of library content and services” and its features are summarized in ““What is WorldCat.org?”” (<https://www.worldcat.org/about>). WorldCat began operation in January 1998 as a free web portal to the collections of more than 10,000 libraries worldwide. Through WorldCat, users can search for information resources in their local libraries and libraries around the world. WorldCat allows users to search for books, CDs, videos, and many new types of digital content, such as audiobooks, in many languages. Users can also retrieve research materials and article citations with links to their full text. After an item is retrieved, WorldCat helps users identify a library nearby that holds the item or all the libraries that hold the item. WorldCat is an efficient way to explore the content held by more than 10,000 libraries around the world. WorldCat is publicly accessible, and there is no fee to perform a search on WorldCat.

25. Library online catalogs gained acceptance in the early 1980s and many libraries migrated their systems to the World Wide Web in the mid-1990s. Library online catalogs are based on MARC records that represent their collections in order to help the public understand what materials are publicly accessible in those libraries. Most libraries with online catalogs have made their catalogs freely available on the

Web. These online catalogs offer user-friendly search interfaces. Strong user interest in keyword searches and the popularity of Google have led to the “googlization” of library search systems. As a result, many library catalogs now provide a single search box for users to conduct keyword searches, with additional support for searches by author, title, subject terms, and other data elements such as ISBN (International Standard Book Number). Library catalogs these days also offer features for users to narrow their search results by language, year, format, and other elements. Many libraries display MARC records on their online catalogs with labels for the data elements to help the public interpret MARC records. Many libraries also offer the option to display MARC records in MARC fields.

26. Libraries create MARC records for works they acquire, including books, serials, motion pictures, and publications in other formats. Monograph cataloging is fairly common in libraries, and most libraries make a newly cataloged monograph available to the public soon after the cataloging work is completed, usually within a week. Libraries can create original cataloging records or use an existing record in OCLC to create a copy cataloging record. As soon as the cataloging record is completed, it is added to the library’s online catalog for users. If the record is an original record, it is also entered into the OCLC system. If it is a copy cataloging record, the library’s holding symbol is attached to the existing original record in the OCLC system to facilitate searching and interlibrary loan.

27. Conference proceedings can be cataloged as monographs or serials, depending on a library's policy. Libraries usually choose to catalog conference proceedings as monographs because records for monographs are easier for users to discover and understand, and access to individual conference proceedings becomes easier. Once a record for a conference proceedings is found, users can see the title, conference name, subjects, and related contributors clearly identified in the record and the call number will enable users to access the desired title quickly. Conference proceedings cataloged as monographs are treated as regular monographs, and the newly cataloged monographs typically become publicly accessible soon after the cataloging work is completed, usually within a week. When conferences have the same conference name over time and are held on a regular basis, libraries may choose to catalog the proceedings of such conferences as serials. This means that only one serial record is created for all the proceedings of a named conference, and no individual records are created for newly received conference proceedings. This approach saves cataloging time, and newly received conference proceedings are made available for user access soon after serial check-in, usually within one week.

28. The cataloging of serials and the serial check-in process are discussed here to show how libraries usually provide access to newly received serial issues. According to the glossary of the *RDA: Resource Description and Access* cataloging standard, a serial is "a mode of issuance of a manifestation issued in successive parts,

usually bearing numbering, that has no predetermined conclusion. A serial includes a periodical, monographic series, newspaper, etc.” (RDA Toolkit at https://original.rdatoolkit.org/rdagloss_rdaregistry.info-termList-ModelIssue-1003_1.html, subscription required for access). Because the publisher of a serial makes new issues of the serial available successively, a customary cataloging practice is to create one bibliographic record for the serial, and the serial record (encoded in MARC) typically provides information on the beginning date and frequency of the serial, not the dates of individual issues. In other words, libraries typically do not create MARC records for individual issues of a serial. Instead, they rely on a serial check-in system to track the receipt of new issues. A common check-in practice is to date stamp a new issue when it arrives. This practice has become automated since the late 1990s, and libraries now vary in how they share the receipt date of a new serial issue with the public. Some libraries use a date stamp, some affix a label to indicate the receipt date, some pencil in the receipt date, and some do not provide the information to the public.

29. The serial check-in process usually takes less than an hour, and one of the steps involves placing a date stamp on the new issue to document the date the issue is checked in. After that, the holdings information of the serial is updated in the library’s catalog so that users know which issues are available for request or access. After serial check-in is completed, the new issue is placed on the shelf with

the previous issues of the serial. Libraries with a public periodical room typically place new issues in the periodical room for easy user access. Because information presented in serials often reflects latest discovery, a general practice of libraries is to make new issues of serials available for user access soon after they are checked in, usually within a week.

II. Authentication and Public Availability of *Begault* (Ex. 1006)

A. Authentication

30. **Ex. 1006** is a true and correct copy of *3-D Sound for Virtual Reality and Multimedia* by D. R. Begault (“*Begault-2000*”) that I obtained from the NASA Technical Reports Server (NTRS). When I began my research on this work, I searched Google Scholar for records for *Begault* and found a link that led me to the metadata record for this work at <https://ntrs.nasa.gov/citations/20010044352> on NTRS. I followed the download link in this metadata record to obtain a copy of *Begault-2000*. This copy is presented as **Ex. 1006** in this Declaration.

31. Page 1 of **Ex. 1006** is the cover that shows the title and author of this work, identifies it as “NASA/TM-2000-209606” and indicates that it was published in “August 2000” by the National Aeronautics and Space Administration, Ames Research Center of Moffett Field, California. Page 2 is the acknowledgement page that shows this work is available from the NASA Center for AeroSpace Information of Hanover, MD and the National Technical Information Service of Springfield, VA.

Pages 3 to 6 (internal pages v to viii) are the table of contents that shows this work has six chapters, bibliographic references that begin on internal page 213 and an index that begins on internal pages 229. Page 7 (internal page ix) is the “Preface to the NASA Technical Memorandum version” by Begault who states that “[s]ince its publication in 1994, *3-D Sound for Virtual Reality and Multimedia* has received considerable attention in the audio and virtual reality community ... I have continued to receive many requests for this book since it went out of print in 1998, and so have decided to provide this facsimile of the original printing for virtual acoustic researchers and enthusiasts.”

32. Internal page 244 of **Ex. 1006** is the “Report Documentation Page” that shows this work is a “Technical Memorandum,” the report date is “August 2000,” the National Aeronautics and Space Administration is the sponsoring agency, and “NASA/TM-2000-209606” is the sponsoring agency report number. This page also shows an abstract that describes the topics covered by each of the six chapters and indicates this technical memorandum “is a reprint of the 1994 book from Academic Press.” In addition, this page shows this technical memorandum has a total of 244 pages, its subjects are “Virtual reality,” “Acoustics,” and “Human-machine interfaces.” This page also shows that the security classification of *Begault-2000*, the report documentation page, and the abstract is “Unclassified,” meaning there is no access restriction on the report, the document page or the abstract.

33. **Ex. 1006** is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, the text on each page appears to flow seamlessly from one page to the next, and there are no visible alterations to the document. Furthermore, this copy of *Begault-2000* was found in the custody of NASA, the sponsoring agency of this report, a place where, if authentic, it would likely be found. I therefore see no reason to question the authenticity of this copy of *Begault-2000*.

B. NASA Metadata Record

34. **Appendix 1006A** is a true and correct copy of the NASA metadata record for *Begault* that I obtained from the NASA Technical Reports Server (NTRS). I personally located, identified and obtained this metadata record. This is the type of record experts in my field would reasonably rely upon when forming their opinion. The NASA metadata record is presented as **Appendix 1006A** in this Declaration.

35. Page 1 of **Appendix 1006A** shows the metadata record is available at <https://ntrs.nasa.gov/citations/20010044352>. The metadata record shows the title, abstract, document ID, and document type of *Begault-2000*. The “Authors” field shows Begault as the first author. The “Publication Date” field shows this work was published on “August 1, 2000” and the “Date Acquired” field shows this work was acquired by NTRS on “September 7, 2013,” making *Begault-2000* discoverable on NTRS from that date on. The metadata record also shows the report/patent numbers

and the funding number. The “Distribution Limits” field shows the work can be distributed to the public, and the “Copyright” field shows this report is a “Work of the US Gov. Public Use Permitted.” The metadata record also shows this work is available for download. The title, abstract, first author, publication date, report number, funding number, and distribution limit match the information presented in **Ex. 1006**, confirming this metadata record represents *Begault-2000*.

C. U.S. Government Publications Catalog Records

36. Because the NASA metadata record (**Appendix 1006A**) indicates *Begault-2000* is a work of the US government, I searched the Catalog of the U.S. Government Publications (CGP) to determine if any records were created for this work, and the search results showed that GPO (Government Publications Office) cataloged the microfiche version of *Begault-2000* and made it discoverable in their online catalog in 2002. The library records are presented as **Appendix 1006B** in this Declaration.

37. **Appendix 1006B** is a true and correct copy of the bibliographic record and MARC record for the microfiche version of *Begault-2000*. I personally located, identified, and obtained these library records. This is the type of record experts in my field would reasonably rely upon when forming their opinion.

38. Pages 1 to 2 of **Appendix 1006B** are the bibliographic record for the microfiche version of *Begault-2000* that shows the title, author, publisher and

distributor, series title and numbering, and the “August 2000” publication date on the cover. The information in these fields matches the information presented in the copy obtained from the NASA Technical Reports Server (**Ex. 1006**), confirming this record represents *Begault-2000*. Since 1895 the United States Government Printing Office (GPO) has managed the Federal Depository Library Program (FDLP) to provide free public access to U.S. federal government publications. The print format was the dominant format for document distribution for many years, and by 1978 US government publications were also distributed in microfiche (source: Powell, M. S. (1999), *The US Federal Depository Library Program and US Government Information in an Electronic Environment: Issues for the Transition and the Millennium*). Because microfiche was a common format to distribute US government publications to depository libraries, GPO cataloged the microfiches and made GPO records available to depository libraries for copy cataloging to facilitate public discovery and access to government publications. **Appendix 1006B** is an example of this type of record. The “SuDoc Number” field shows the “Superintendent of Documents” number that is the type of call number typically applied to federal documents. The first general note shows the shipping list no. for the microfiche version of *Begault-2000* is “2002-0039-M.” Two Linking Field notes show this work is also available in print and online.

39. Pages 3 and 4 are the MARC record for the microfiche version of *Begault-2000*. The first six digits of Field 008 show the MARC record was created on “021030” (*i.e.*, October 30, 2002), and Subfield “a” of Field 040 shows the record was originally created by “GPO” (the Government Printing Office at the time, later changed to Government Publications Office). Data from Fields 008 and 040 inform my opinion that since October 30, 2002, the microfiche version of *Begault-2000* has become discoverable in the catalog of the Government Printing Office. **Appendix 1006B** shows that Begault is included as the author in Field 100, title is recorded in Field 245, a variant title is included in Field 246 to help users discover this work, the NASA Center for AeroSpace Information is included in Field 264 to help users obtain this work, Field 533 explains that this MARC record represents a microfiche reproduction of the original work, and Field 710 shows Ames Research Center can be used to discover this work.

40. Subjects of *Begault-2000* are represented in Field 086 by a Superintendent of Documents Classification number of “NAS 1.15:209606” and by six Library of Congress subject headings in Fields 650, with “Sound,” “Sound-waves,” “Virtual reality,” “Human-computer interaction,” “Signal processing,” and “Psychoacoustics” as the topics.

41. This MARC record shows that *Begault-2000* was published in 2000, and the MARC record for the microfiche version has made it discoverable at the

online catalog of the Government Printing Office Library since October 30, 2002. Interested users would have been able to conduct subject searches by the SuDocs number and by the Library of Congress subject headings to discover this work. They would also have been able to search for this work by the author, title, variant title, and the publisher.

D. Stanford University Records

42. **Appendix 1006C** is a true and correct copy of the bibliographic record and MARC record for the microfiche version of *Begault-2000* that I obtained from the online catalog of the Stanford University Library. I personally searched for records for this work by its title and located, identified, and obtained these records. This is the type of record experts in my field would reasonably rely upon when forming their opinion.

43. Pages 1 to 3 of **Appendix 1006C** are the bibliographic record that shows the title, author, imprint, physical description, series, contributor, subjects, publication date, title variation, and notes for *Begault-2000*. Pages 4 and 5 are the MARC record. The first six digits of Field 008 show the original MARC was created on “021030” (*i.e.*, October 30, 2002), Subfield “a” of Field 040 shows “GPO” created the original record, and Field 916 shows *Begault-2000* was cataloged by the Stanford University Library on “20021212” (*i.e.*, December 12, 2002). Data from Fields 008, 040 and 916 inform my opinion that the Stanford University Library

used the original MARC record created by GPO on October 30, 2002, for copy cataloging and completed their copy cataloging record on December 12, 2002, making the microfiche version of *Begault-2000* discoverable in their online catalog from that date on.

44. Because the Stanford University Library MARC record is a copy cataloging record based on the GPO MARC record, it is natural that the two records have many fields in common, including the SuDoc Classification number in Field 086, the author in Field 100, title in Field 245, variant title in Field 246, publisher and distributor information in Field 260 (or 264), physical description in Field 300, series information, notes, microfiche reproduction note in Field 533, subject heading fields in Fields 650, and the publisher in Field 710. In addition, the Stanford University Library MARC record has a Field 530 that indicates this work is also “available via Internet from the NTRS web site. Address as of 5/22/06: <http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/200100443252%5F2001071187.pdf>; current access is available via PURL” and the PURL in Field 856 shows the permanent URL of this work is <https://purl.fdlp.gov/GPO/LPS70089>, which led me to an online version *Begault-2000*. I have compared the online version with **Ex. 1006** and concluded that the two copies are the same.

45. The Stanford University Library records (**Appendix 1006C**) is a copy cataloging record completed on December 12, 2002, making *Begault-2000*

discoverable in the library online catalog from that date on. Users would have been able to conduct subject searches by the SuDocs number and by the Library of Congress subject headings to discover it. They would also have been able to search for this work by the author, title, variant title, and the publisher. In addition, when the online version of *Begault-2000* became available in May 2006, the Stanford University Library added a note to alert users of the availability of the online version and a PURL note in Field 856 to lead users to the online version.

E. Library of Congress records for *Begault-1994*

46. The “Preface to the NASA Technical Memorandum version” by Begault in **Ex. 1006** states that the technical memorandum (NASA/TM-2000-209606) was published in 1994 (“*Begault-1994*”), and in response to many requests, he decided “to provide this facsimile of the original printing for virtual acoustic researchers and enthusiasts.” To determine whether *Begault-1994* was available in libraries, I searched WorldCat by the title of this book and found a record at <https://worldcat.org/title/30701019> that shows the Library of Congress, the US Naval Academy Library, and Stanford University Library are three of the holding libraries. I then searched the online catalog of the Library of Congress for their records for this book and the retrieved records at <https://lccn.loc.gov/94028168> show the library has two copies. These records are presented as **Appendix 1006D** in this Declaration.

47. **Appendix 1006D** is a true and correct copy of the bibliographic and MARC records for *3-D Sound for Virtual Reality and Multimedia* by Durand R. Begault that was originally published by AP Professional in 1994. I personally located, identified, and obtained these records. These are the type of record experts in my field would reasonably rely upon when forming their opinions.

48. Pages 1 to 2 are the bibliographic record that shows the author, title, publisher, physical description, ISBN (International Standard Book Number), subjects, and classification numbers for this book. The “Item Availability” area shows the call number for this book is “QA76.9.H85 B44 1994” for two copies stored offsite, and users can request the copies at the Jefferson or Adams Building Reading Rooms of the Library of Congress.

49. Pages 3 and 4 are the MARC record. The first six digits of Field 008 show the record was created on “940616” (*i.e.*, June 16, 1994), and the “s1994” code following the record creation date indicates this book has a single publication date of 1994. Field 955 records local cataloging activities on this book, and the last subfield shows “CIP ver. pv06 11-04-94.” This note indicates the original record was a CIP record (Cataloging in Publication record created before publication of the book) and the record was verified on November 4, 1994. Subfield “a” of Field 040 shows “DLC” created the record. According to the *Directory of OCLC Members* (<https://www.oclc.org/en/contacts/libraries.html>), “DLC” is the OCLC library

symbol for the Library of Congress. Data from Field 008, 955 and 040 inform my opinion that the Library of Congress created a CIP record for *Begault-1994* on June 16, 1994, before the book was published, and the CIP record was verified by Library of Congress catalogers on November 4, 1994. As discussed above, a common library practice is to process newly cataloged books quickly for public access and the processing work is usually completed within a week after the cataloging work is completed. Based on my experience with the Library of Congress and their collections, it takes one to three months for a newly cataloged book to become available for public access at the Library of Congress. It is therefore my opinion that *Begault-1994* would have become discoverable in the online catalog of the Library of Congress on June 16, 1994, when the CIP record was created, and, after processing, the library copy would have become publicly accessible between December 1994 and February 1995 at the Library of Congress.

50. Field 020 shows the ISBN of *Begault-1994*, Field 100 shows Begault as the author, Field 245 shows the title and statement of responsibility, and Field 260 shows AP Professional of Boston published this book in 1994. Field 300 shows the physical details of this work, Field 504 shows the book includes bibliographical references and index, and Field 740 shows a variant title is included to help users discover this book.

51. Subjects of this book are represented in Field 050 by a Library of Congress Classification number of “QA76.9.H85” that represents “Human-computer interaction” and in Field 082 by a Dewey Decimal Classification number of “621.389/3” that represents “Sound recording and reproducing system.” Subjects are also represented in Fields 650 by five Library of Congress subject headings: Human-computer interaction, Virtual reality, Multimedia systems, Computer sound processing, and Sound in virtual reality. These subject representations enable users to conduct subject searches to discover *Begault-1994*.

52. The MARC record (**Appendix 1006D**) informs my opinion that *Begault-1994* became searchable in the online catalog of the Library of Congress on June 16, 1994, when the CIP record was created. Since June 1994 the MARC record has supported users to discover *Begault-1994* in the library’s online catalog by subjects, author, title, variant title, and ISBN. After processing, the library copy would have become publicly accessible between December 1994 and February 1995.

F. Copyright Registration Record for *Begault-1994*

53. **Appendix 1006E** is a true and correct copy of the copyright registration record for *3-D Sound for Virtual Reality and Multimedia* by Durand R. Begault that was originally published by AP Professional in 1994. I obtained this record from the public catalog of the United States Copyright Office in the Library of Congress by

first accessing their website at <http://www.copyright.gov>, following the “Learn More” link under “Search Copyright Records” and selecting the “Official Public Catalog (1978-present)” link to search for records by the author. I personally located, identified and obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

54. The title, author, imprint, copyright date, description and copyright claimant information match the information presented in the Library of Congress records (**Appendix 1006D**). The record shows “1994” is the date of creation, “1994-09-23” is the date of publication, and this work was registered with the US Copyright Office on “1994-10-19” and assigned a registration number of “TX0003918351.”

G. US Naval Academy Library Records for *Begault-1994*

55. My research on WorldCat identified the US Naval Academy Library as another holding library of *Begault-1994*, so I obtained the records for this work from their online catalog to determine the public availability date. I personally located, identified, and obtained these records. They are the type of record experts in my field would reasonably rely upon when forming their opinion. These records are presented as **Appendix 1006F** in this Declaration.

56. **Appendix 1006F** is a true and correct copy of the bibliographic and MARC records for *Begault-1994* obtained from the US Naval Academy Library. Pages 1 to 3 are the bibliographic record that shows this book is available “at Nimitz

Library Third Floor General Stacks (QA76.9.H85 B44 1994).” The bibliographic record includes title, ISBN, creator, subjects, other title, publisher, creation date, format, and a local note.

57. Page 4 of **Appendix 1006F** is the MARC record. The first six digits of Field 008 show the record was originally created on “940616” (*i.e.*, June 16, 1994). Field 005 is a machine-generated field that records the last time this MARC record was modified, and it shows “19951121” (*i.e.*, November 21, 1995) as the last record modification date. Subfield “a” of Field 040 shows “DLC” (*i.e.*, Library of Congress) created the original record, and Subfield “d” shows “UNA” used the original MARC record for copy cataloging. According to the *Directory of OCLC Members* (<https://www.oclc.org/en/contacts/libraries.html>), “UNA” is the OCLC library symbol for the US Naval Academy. Based on the data in Fields 008, 005 and 040, it is my opinion that the US Naval Academy Library used the Library of Congress record to create a copy cataloging record for *Begault-1994*, and their record was last modified by November 21, 1995, meaning this record would have been in their online catalog no later than November 21, 1995, and the record would have made *Begault-1994* discoverable at least from that date on at this library.

58. Because the US Naval Academy MARC record (**Appendix 1006F**) is based on the Library of Congress MARC record (**Appendix 1006D**), the former contains the same data as the latter, except for a few fields of local details. **Appendix**

1006F shows that the interested public would have been able to conduct subject searches to discover *Begault-1994*. They would also have been able to discover this book by the author, title, variant title, and ISBN. The copy of this book would have become publicly accessible at this library by November 28, 1995.

H. Stanford University Library Records for *Begault-1994*

59. My research on WorldCat also identified the Stanford University Library as another holding library of *Begault-1994*, so I obtained their records from their online catalog to determine the public availability date. I personally located, identified, and obtained these records. They are the type of record experts in my field would reasonably rely upon when forming their opinion. These records are presented as **Appendix 1006G** in this Declaration.

60. **Appendix 1006G** is a true and correct copy of the bibliographic and MARC records for *Begault-1994* obtained from the Stanford University Library. Pages 1 to 3 are the bibliographic record that shows this book has a call number of QA76.9.H85 B44 1994, is stored at SAL3 (off-campus storage), and is available for user request. The bibliographic record shows the title, author, imprint, physical description, notes, subjects, and a variant title.

61. Pages 4 and 5 of **Appendix 1006G** is the MARC record. The first six digits of Field 008 show the record was originally created on “940616” (*i.e.*, June 16, 1994). Subfield “a” of Field 040 shows “DLC” (*i.e.*, Library of Congress) created

the original record, and Field 916 shows *Begault-1994* was cataloged on “19960205” (*i.e.*, February 5, 1996). Based on the data in Fields 008, 040, and 916, it is my opinion that the Stanford University Library used the Library of Congress record to create a copy cataloging record for *Begault-1994*, and completed their record on February 5, 1996. These data mean that the Stanford University Library MARC record was in their online catalog on February 5, 1996, making *Begault-1994* discoverable from that date on.

62. Because the Stanford University Library MARC record (**Appendix 1006G**) is based on the Library of Congress MARC record (**Appendix 1006D**), the former contains the same data as the latter, except that the Stanford University Library record uses four Library of Congress subject headings, while the Library of Congress record uses five Library of Congress subject headings. In addition, the Stanford University Library record includes a contents note and a publisher’s summary. **Appendix 1006G** shows that the interested public would have been able to conduct subject searches to discover *Begault-1994*. They would also have been able to discover this book by the author, title, variant title, and ISBN. The copy of this book would have become publicly accessible at this library by February 12, 1996.

I. Usage Record

63. Actual usage of a work is reflected by other publications that make reference to it. The citation history of Google Scholar shows *Begault-1994* was cited 1,791 times. **Appendix 1006H** shows five 1995 citations to *Begault-1994* to demonstrate early usage. The earliest citation appeared in August 1995. After *Begault-2000* was published by NASA as a Technical Memorandum, researchers have continued to cite the original work, because *Begault-2000* is a facsimile of the original printing, and a common citation practice is to cite the original source when it is known and available. I have included five 2001 citations in **Appendix 1006H** to show that *Begault-1994* continued to be cited after *Begault-2000* became available. Page 3 of **Appendix 1006H** is a screen capture of Google Scholar that shows *Begault-1994* was cited 1,791 times, page 4 is a screen capture showing it was cited 11 times in 1995, and page 5 is a screen capture showing it was cited 53 times in 2001.

J. Summary of My Opinion on *Begault-2000* and *Begault-1994*

64. *Begault-2000* (NASA/TM-2000-209606) (**Ex. 1006**) was published by NASA in August 2000, and the NASA metadata record (**Appendix 1006A**) shows that this work was added to the NASA Technical Reports Server system on “September 7, 2013,” making it discoverable in this information system from that date on. Because *Begault-2000* is a US federal government publication, it was

distributed in microfiche by the Government Printing Office (GPO) to a network of libraries in the Federal Depository Library Program, and GPO created a MARC record for the microfiche version on October 30, 2002 (**Appendix 1006B**) to facilitate the discovery and access to *Begault-2000* at depository libraries. As a depository library, the Stanford University Library used the GPO record for copy cataloging and completed their record on December 12, 2002 (**Appendix 1006C**). The Stanford University Library record later added a note indicating the online version of *Begault-2000* was available on the NTRS web site by May 22, 2006, and a PURL (permanent URL) note is included for users to access the online version at <https://purl.fdlp.gov/GPO/LPS70089>; this link leads to the current PURL of this work at <https://permanent.fdlp.gov/lps70089/20010044352.pdf>. Based on these records, it is my opinion that *Begault-2000* was published in August 2000, a microfiche version was distributed to libraries in the Federal Depository Library Program, the microfiche version was cataloged by GPO on October 30, 2002, making the microfiche version discoverable from that date on in the online catalog of the Government Printing Office. The GPO MARC record includes two notes to alert users of the availability of the print and online versions of *Begault-2000*. After the Stanford University completed their copy cataloging work on December 12, 2002, they updated their record with a note that by May 22, 2006, the online version of *Begault-2000* could be accessed via the permanent URL included in their record.

It is therefore my opinion that the microfiche version of *Begault-2000* would have been discoverable at the GPO library and the Stanford University Library by October and December of 2002, respectively, and interested users would have been able to access the microfiche version within a week after the cataloging work was completed. In addition, the Stanford University Library record shows that by May 22, 2006, the online version of *Begault-2000* was publicly accessible. The NTRS metadata record (**Appendix 1006A**) shows *Begault-2000* would have been discoverable in that information system by September 7, 2013.

65. Because *Begault-2000* is a facsimile of the original printing of *Begault-1994*, I obtained records from three libraries to show public accessibility of *Begault-1994* at libraries. The Library of Congress created a Cataloging in Publication record for *Begault-1994* on June 16, 1994, making this book discoverable in the library catalog from that date on. After the Library of Congress verified the CIP record on November 4, 1994, their copy would have become publicly accessible between December 1994 and February 1995. The copyright registration record (**Appendix 1006E**) shows *Begault-1994* was published on September 23, 1994. The MARC record from the US Naval Academy Library shows their library used the Library of Congress record for copy cataloging and they completed their cataloging work no later than November 21, 1995. The MARC record from the Stanford University Library shows they also used the Library of Congress record for copy cataloging and

completed their cataloging work on February 5, 1996. These records inform my opinion that *Begault-1994* became discoverable in June 1994, and the copy would have become publicly accessible between December 1994 and February 1995 at the Library of Congress. The book became discoverable in November 1995 at the US Naval Academy Library. It also became discoverable in February 1996 at the Stanford University Library. Citation history shows the earliest citation to *Begault-1994* appeared in August 1995, and after *Begault-2000* became available in August 2000, researchers have continued to cite *Begault-1994* because it is the original source.

III. Authenticity and Public Availability of *Finnegan* (Ex. 1005)

A. Authentication

66. **Ex. 1005** is a true and correct copy of “Compensating for Distance Compression in Audiovisual Virtual Environments Using Incongruence” by Finnegan et al. (“*Finnegan*”) in *CHI 2016 : Proceedings, the 34th Annual CHI Conference on Human Factors in Computing Systems*, pp. 200-212, that I obtained from the ACM Digital Library. When I began researching this article, I searched Google Scholar for records for *Finnegan*, and the entry for this article led me to the ACM metadata record for this article at <https://dl.acm.org/doi/abs/10.1145/2858036.2858065> in the ACM Digital Library. I followed the link for “Get Access” to purchase *Finnegan* from the publisher. This

ACM copy is presented as **Ex. 1005** in this Declaration.

67. **Ex. 1005** is a true and correct copy of *Finnegan* obtained from the ACM Digital Library, the digital library created and maintained by the Association for Computing Machinery (ACM). Page 1 (internal page 200) shows the title, authors, abstract, author keywords and ACM Classification Keywords for this article. The bottom of this page shows <http://dx.doi.org/10.1145/2858036.2858065> as the article DOI (Digital Object Identifier), “2016” as the copyright date and ACM as the copyright holder, “978-1-4503-3362-7” as the ISBN of this work, and “Chi’ 16, May 07-12, 2016, San Jose, CA, USA” as the conference information. A running title of “3D Virtual Space, #chi4good, CHI 2016, San Jose, CA, USA” appears at the top of all the pages of this article. **Ex. 1005** shows *Finnegan* has a total of 13 pages, including two equations, four figures, one table, and 46 references.

68. The ACM copy of *Finnegan* (**Ex. 1005**) is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, the text on each page appears to flow seamlessly from one page to the next, and there are no visible alterations to the document. Moreover, **Ex. 1005** was found in the custody of a digital library owned and managed by the publisher, a place where, if authentic, it would likely be found. Accordingly, I see no reason to question the authenticity of the ACM copy of *Finnegan* (**Ex. 1005**).

B. ACM Database Record for *Finnegan*

69. **Appendix 1005A** is a true and correct copy of the metadata record for *Finnegan* obtained from the ACM Digital Library. I personally located, identified, and obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions. I used screen captures of the record to produce this appendix.

70. Page 1 of **Appendix 1005A** shows the URL of the ACM metadata record, the title, authors, publication source, and publication history (“Published: 07 May 2016”), link for article access, and an editorial note indicating “a corrigendum was issued for this article on February 6, 2020.” Page 2 shows the article abstract, which is the same as the abstract in the ACM copy of *Finnegan* (**Ex. 1005**). Page 3 shows a YouTube video entitled “Compensating for Distance Compression in Audiovisual Virtual Env...” and the “Supplemental Material” area shows interested users can play this MP4 file or download it. Page 4 shows two more items for download and the beginning of the reference list. Page 5 shows citations and ACM index terms for this article, Page 6 shows recommended articles that may be related to this article. On the left side of the ACM metadata record, a link is provided for “*CHI '16: Proceedings of the 2016 CHI*.” This link leads to the ACM metadata record for the *CHI '16* proceedings at <https://dl.acm.org/doi/proceedings/10.1145/2858036>. Page 9 is the ACM metadata

record that identifies this work as “CHI ’16: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems,” and shows Jofish Kaye and Allison Druin as the general chairs of the conference, the “Association for Computing Machinery” of New York as the publisher, “978-1-4503-3362-7” as the ISBN of this work, and “07 May 2016” as the publication date. Page 10 shows citation count, download numbers of the past six weeks, past 12 months, and cumulative number. Page 11 shows the front matter of the conference proceedings (the title page, copyright, chair’s welcome, and contents) is freely available to the public at <https://dl.acm.org/action/showFmPdf?doi=10.1145%2F2858036>. I included the first six pages of this front matter in **Appendix 1005A** as pages 12 to 17.

71. Page 12 is the cover that shows a logo of “CHI 2016 #ch4good” and indicates that CHI 2016 took place from May 7 to 12 in San Jose, CA, USA, and the ACM SIG CHI contributes to this publication. The cover also shows this publication is the proceedings of the “34th Annual Chi Conference on Human Factors in Computing Systems.” Page 13 is the copyright page that shows a “2015” copyright date and the Association for Computing Machinery, Inc. as the copyright holder. It also shows “978-1-4503-3362-7” is the ISBN assigned to this work, and ACM of New York is the publisher. Pages 14 and 15 show the conference chair’s message, and pages 16 and 17 (internal pages v and vi) are part of the table of contents that

shows *Finnegan* is included in “Session: 3D Virtual Space” and is part of volume 1, running from pages 200 to 212.

C. Hamburg Library Record & OCLC FirstSearch Record

72. To determine if *Finnegan* was available in libraries, I searched WorldCat by the ISBN of the conference proceedings for records, and found the earliest library record was created by a German library. The WorldCat record at <https://www.worldcat.org/title/949884930> shows “Staats- und Univrsitätsbibliothek Hamburg Carl von Ossietzky” (Hamburg State and University Library Carl von Ossietzky) holds this conference proceedings. I obtained this library’s record for the conference proceedings to verify the record content, and also obtained a copy of this library record from the WorldCat database on OCLC FirstSearch to determine the record creation date. These records are presented as **Appendix 1005B** in this Declaration.

73. **Appendix 1005B** is a true and correct copy of the WorldCat record, the Hamburg State and University Library record and the FirstSearch record for the conference proceedings containing *Finnegan*. I personally located, identified, and obtained these records. They are the type of records experts in my field would reasonably rely upon when forming their opinions. Pages 1 to 3 are the WorldCat record that shows the title, authors, genre, publisher, physical description, ISBN, OCLC number, subjects, additional form entry, notes, and a note about full text

access at the ACM Digital Library. Page 4 is a library record in German that shows the proceedings was cataloged by the “Staats- und Universitätsbibliothek Hamburg Carl von Ossietzky” and they used “#chi4good CHI 2016” as the main title. The record includes CHI and the Association for Computing Machinery, Special Interest Group on Computer and Human Interaction as the corporate authors. It also includes three forms of the conference name, the language of this work, the publisher, physical description (“Online-Ressource : Illustrationen”), genre (“Konferenzschrift”), ISBN, and subject terms assigned to this work. In addition, the record includes a variant title and indicates this work has a print version published by the same publisher. The title, variant title, conference names, language, publisher, and format information are consistent with the information presented in the front matter of the conference proceedings included in **Appendix 1005A**, confirming the record represents the conference proceedings containing *Finnegan*.

74. Pages 5 and 6 are the library’s record that I obtained from the WorldCat database on OCLC FirstSearch, which is a subscription-based search system that hosts many databases of scholarly materials. OCLC FirstSearch is different from the WorldCat on the Internet, which is a free web portal for information seekers to explore the collections of more than 10,000 libraries worldwide. The records in OCLC FirstSearch contain more technical details than records available on the free web portal, WorldCat. The record on OCLC FirstSearch for the conference

proceedings shows “#chi4good” as the main title, and “Staats & Universitätsbibliothek Hamburg” as the holding library. The data in the German record (page 4) are contained in this OCLC FirstSearch record (pages 5 and 6), including the title, corporate authors, conference names, publisher, year of publication, description (“Online-Ressource Illustrationen”), language, ISBN, access method, genre (“Konferenzschrift”), note, other format available, other titles, and two subject terms. The “Update” field shows this record was last updated on “20220803” (*i.e.*, August 3, 2022). The “Date of Entry” field on page 6 shows this record was first entered into OCLC on “20160517” (*i.e.*, May 17, 2016), the accession number field shows a record number of OCLC 949884930, and the database field shows this record is in the WorldCat database. Taken together, these three records in **Appendix 1005B** inform my opinion that the conference proceedings containing *Finnegan* was cataloged by “Staats- und Universitätsbibliothek Hamburg Carl von Ossietzky” and their MARC record was entered into OCLC on May 17, 2016, making the record discoverable from that date on in their online catalog, in OCLC FirstSearch, and also on WorldCat, the free web portal. Interested users would have been able to conduct subject searches to locate this proceedings. They would also have been able to use the ISBN, conference names, title of the proceedings, variant title, and sponsor to locate this proceedings.

D. Usage Record

75. Actual usage of a publication is reflected by the papers that make reference to it. Citation history on Google Scholar shows *Finnegan* has been cited at least 54 times. I have identified two 2016 citations to demonstrate early usage:

(1) Janzen, I. (2016, August). Modeling distal pointing on large screens: the influence of target depth (Doctoral dissertation, University of British Columbia).

(2) Bates, E., & Boland, F. (2016, September). Spatial music, virtual reality, and 360 media. In *Audio Engineering Society Conference: 2016 AES International Conference on Audio for Virtual and Augmented Reality*. Audio Engineering Society.

E. Summary of My Opinion on *Finnegan*

76. The ACM copy of *Finnegan* (**Ex. 1005**) shows it was published on May 7, 2016 by the ACM. The ACM metadata record (**Appendix 1005A**) shows *Finnegan* has been discoverable on the ACM Digital Library, and users whose institutions subscribe to the ACM Digital Library can access *Finnegan* without paying a fee, and other users can purchase this article from this digital library. Records in **Appendix 1005B** show that “Staats- und Univrsitätsbibliothek Hamburg Carl von Ossietzky” (Hamburg State and University Library Carl von Ossietzky) created the earliest library record for the online version of the conference

proceedings containing *Finnegan*, and their record was entered into the WorldCat database on OCLC on May 17, 2016, making the conference proceedings discoverable from that date on in the library's online catalog, the OCLC FirstSearch system, and on WorldCat, the free web portal. The documents I have reviewed inform my opinion that the conference proceedings containing *Finnegan* would have become publicly discoverable from May 17, 2016 on. Citation records show that early citations to *Finnegan* appeared in August and September of 2016.

IV. Authentication and Public Availability of *Algazi* (Ex. 1008)

A. Authentication

77. **Ex. 1008** is a true and correct copy of “The cipic hrtf database” by Algazi et al. (“*Algazi*”) in *Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics*, pp. 99-102, that I obtained from the IEEE Xplore Digital Library (IEEE Xplore) of the Institute of Electrical and Electronics Engineers (IEEE). When I began researching this article, I searched Google Scholar for records for *Algazi*, and the entry for this article led me to the IEEE metadata record for this article at <https://ieeexplore.ieee.org/abstract/document/969552> in IEEE Xplore. I used the PDF link in this record to purchase *Algazi* from the publisher. This IEEE copy is presented as **Ex. 1008** in this Declaration.

78. **Ex. 1008** is a true and correct copy of *Algazi* obtained from IEEE

Xplore, the digital library created and maintained by the Institute of Electrical and Electronics Engineers. Page 1 (internal page 99) shows the title, authors, and abstract of this article. The bottom of this page shows the article appears in a meeting that took place from “21-24 October 2001, New Paltz, New York” and the bottom of page 2 (internal page 100) shows “IEEE Workshop on Applications of Signal Processing to Audio and Acoustics 2001” is the name of the meeting. **Ex. 1008** shows *Algazi* has a total of four pages, including five sections, seven figures, one table and 14 references.

79. The IEEE copy of *Algazi* (**Ex. 1008**) is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, the text on each page appears to flow seamlessly from one page to the next, and there are no visible alterations to the document. Moreover, **Ex. 1008** was found in the custody of a digital library owned and managed by the publisher, a place where, if authentic, it would likely be found. Accordingly, I see no reason to question the authenticity of the IEEE copy of *Algazi* (**Ex. 1008**).

B. IEEE Database Record for *Algazi*

80. **Appendix 1008A** is a true and correct copy of the metadata record for *Algazi* obtained from IEEE Xplore. I personally located, identified, and obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions. I used screen captures of the record to produce this

appendix.

81. Page 1 of **Appendix 1008A** shows the title and authors of the *Algazi* article. It also shows IEEE as the publisher, and indicates *Algazi* has 444 paper citations, 23 patent citations, and 3,710 full text views. The abstract in this record is identical to the abstract in the IEEE copy (**Ex. 1008**), and the record shows there are five sections in this article. Page 2 of the IEEE metadata record shows *Algazi* was published in the “Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics” (Cat. No.01TH8575) whose ISBN (International Standard Book Number) is “0-7803-7126-7.” The record also shows the conference date is “24-24 October 2001” and the conference location is “New Platz, NY, USA.” The record also shows the article DOI (digital object identifier) is “10.1109/ASPAA.2001.969552” and the “Date Added to IEEE Xplore” field shows this metadata record was added to this digital library on “07 August 2002.” The title, authors, abstract, and the name of the meeting in this record match the information presented in the IEEE copy (**Ex. 1008**), confirming this record represents *Algazi*.

82. The IEEE metadata record for *Algazi* includes a direct link to the conference, which leads to an IEEE record for this conference (available at <https://ieeexplore.ieee.org/xpl/conhome/7653/proceeding>). A screen capture of the top of this record is included as page 4 of **Appendix 1008A**. The front matter of this conference is freely available to the public at

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=969527>, and is included in **Appendix 1008A** as pages 5 to 13.

83. Page 5 of **Appendix 1008A** is the cover of the conference proceedings that shows “Proceedings of the 2001 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics” is the title, the conference took place on “October 21-24, 2001, Mohonk Mountain House, New Paltz, New York, USA” and IEEE Signal Processing Society is the publisher. Page 6 is the title page that shows the same title and conference information as the cover. Page 7 is the copyright page that shows a “2001” copyright date and IEEE as the copyright holder. This page also shows “01TH8575” as the IEEE Catalog Number for this proceedings, “0-7803-7126-7” as the ISBN of this work, and “2001091204” as the Library of Congress control number. Pages 8 to 12 (internal pages iii to vii) are the table of contents and internal page v shows *Algazi* was included in “Session 6: Perception” scheduled for October 23, 2001, and the article begins on page 99.

84. Data in the IEEE metadata record for *Algazi* and the front matter of the conference proceedings containing *Algazi* inform my opinion that *Algazi* was published in 2001, and IEEE Xplore indexed the article and added the metadata record to the IEEE Xplore Digital Library on August 7, 2002. The IEEE record made *Algazi* discoverable in IEEE Xplore from that date on. As of August 7, 2002, interested users would have been able to locate the metadata record for *Algazi* and

purchase the article from IEEE or obtain it from an institution that subscribed to the IEEE Xplore Digital Library.

C. Linda Hall Library Copy

85. To determine if *Algazi* was available in libraries, I searched WorldCat for the conference proceedings that contains *Algazi*. I searched by the ISBN of this work for records and located a record at <https://www.worldcat.org/title/48525034> that shows Linda Hall Library is one of the holding libraries. After verifying the holdings information at their online catalog, I requested a scanned copy from the Document Delivery Service of this library. This copy from the Linda Hall Library is included as **Appendix 1008B** in this declaration.

86. Pages 1 to 4 of **Appendix 1008B** are the full text of *Algazi*. I have closely compared this library copy with the IEEE copy (**Ex. 1008**) and found them to be the same. Page 5 is the cover of the conference proceedings containing *Algazi*, page 6 is the title page, page 7 is the copyright page, pages 9 to 13 (internal pages iii to vii) are the table of contents. These pages from the front matter are the same as the front matter obtained from IEEE Xplore and included in **Appendix 1008A**. Page 8 is an information page on the conference that shows a library stamp that indicates this work is held by the Linda Hall Library of Kansas City, Mo., and the upper left corner shows a hand-written annotation of “12-4-01” that indicates this work was added to the library collection on December 4, 2001. The knowledge of this practice

is based on my personal experience with the collections and staff at the Linda Hall Library.

D. Linda Hall Library Records

87. **Appendix 1008C** is a true and correct copy of the bibliographic and MARC records for *Proceedings of the 2001 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics* that contains *Algazi*. I personally located, identified, and obtained these records from the online catalog of the Linda Hall Library. These are the type of records experts in my field would reasonably rely upon when forming their opinions. I used screen captures of these records to produce this appendix.

88. Pages 1 to 3 of **Appendix 1008C** are the bibliographic record that shows the conference proceedings containing *Algazi* is available at “Linda Hall Library Books – 2nd Floor (TK7881.4 .I34 2001).” The “Location Items” area shows the library copy is “loanable” (meaning users can access this work). The detailed record on page 2 shows the title, other titles, creators, subjects, identifiers (ISBNs and OCLC number), publisher, creation date, format, and general notes.

89. Page 4 is the MARC record. The first six digits of Field 008 show the record was created on “011204” (*i.e.*, December 4, 2001). Subfields “a” and “c” of Field 040 show “LHL” created the original MARC record. According to the *Directory of OCLC Members* (<https://www.oclc.org/en/contacts/libraries.html>),

“LHL” is the OCLC library symbol for the Linda Hall Library. Data from Fields 008 and 040 inform my opinion that the Linda Hall Library created a MARC record for the conference proceedings containing *Algazi* on December 4, 2001. This cataloging date is consistent with the collection add date on page 8 of the Linda Hall Library copy of *Algazi* (**Appendix 0012B**). The MARC record creation date means that the conference proceedings containing *Algazi* would have become discoverable in the library online catalog of the Linda Hall Library since December 4, 2001.

90. Field 010 shows “2001091204” as the Library of Congress control number, Fields 020 show the 13-digit and 10-digit ISBNs assigned to this conference proceedings, and Fields 246 show four variant titles are included to help users discover this work. Field 260 shows the publisher and copyright date, Field 300 shows the physical description, Fields 500 show the IEEE catalog number, Field 530 indicates this work is also “available via the World Wide Web” and Field 710 shows the IEEE Signal Processing Society is included to help users discover this work. The Library of Congress control number, ISBN, title, publisher, copyright date, IEEE catalog number and sponsor match the information presented in the front matter of the conference proceedings in **Appendix 1008A**, confirming this record represents the conference proceedings containing *Algazi*.

91. Subjects are represented in Field 090 by a Library of Congress Classification (LCC) number of “TK7881.4” that represents general works on

“Sound systems. Sound recording. Sound reproduction” and in Fields 650 by five Library of Congress subject headings, with “Sound \$x Recording and reproducing \$x Mathematics,” “Signal processing \$x Digital techniques,” “Acoustical engineering,” “Electro-acoustics,” and “Music \$x Acoustics and physics” (“x” indicates a topical subheading) as the main topics, each followed by a form subheading of “Congresses” encoded in subfield “v” (\$v) to indicate the main topics are discussed at a conference. These subject representations support users to conduct subject searches to locate this conference proceedings.

92. This MARC record (**Appendix 1008C**) shows that the conference proceedings containing *Algazi* was published in 2001, and the MARC record was completed on December 4, 2001, making this work discoverable from that date on in the online catalog of the library of the Linda Hall Library. Interested users would have been able to conduct subject searches to discover this work. They would also have been able to use the ISBN, the Library of Congress control number, the conference name, the title, variant titles, the IEEE catalog number, and the sponsor to discover this work. As discussed earlier, a common library practice is to process newly cataloged monographs promptly for public access, usually within a week after the cataloging work is completed. It is therefore my opinion that a copy of this conference proceedings (and *Algazi* contained therein) would have been publicly accessible at this library by December 11, 2001.

E. North Carolina State University Library Records

93. To further demonstrate the use of the Linda Hall Library MARC record (**Appendix 1008C**) for copy cataloging and the availability of the proceedings containing *Algazi* at more libraries, I obtained library records from the North Carolina State University Library. **Appendix 1008D** is a true copy of the bibliographic and MARC records for the conference proceedings containing *Algazi*. I personally located, identified, and obtained these records from the online catalog of the North Carolina State University Library at <https://catalog.lib.ncsu.edu/catalog/NCSU1530971>. These are the type of records experts in my field would reasonably rely upon when forming their opinions. I used screen captures of these records to produce this appendix.

94. Pages 1 to 3 of **Appendix 1008D** are the bibliographic record that shows it represents the print version of the conference proceedings containing *Algazi*, and the “Where to find it” area shows this work is available at the Hunt Library, its call number is “TK7881.4 .I34 2001” and its status is “[a]vailable upon request.” The rest of the bibliographic record shows the meeting name, sponsor, topics, variant titles, publisher, language, physical description, genre, ISBN, OCLC number, Library of Congress control number, and the IEEE catalog number for this work.

95. Pages 4 and 5 are the MARC record. The first six digits of Field 008

show the MARC record was created on “011204” (*i.e.*, December 4, 2001), and subfields “a” and “c” of Field 040 show “LHL” (*i.e.*, Linda Hall Library) created the original MARC record. Field 005 is a machine-generated field that automatically records the last time this record was modified by the North Carolina State University Library, and it shows the library last modified this record on “20020102081052” (*i.e.*, January 2, 2002, 8 a.m., 10 minutes, 52 seconds). Data from Fields 008, 040, and 005 inform my opinion that the North Carolina State University Library used the Linda Hall Library MARC record to create their copy cataloging record and last modified their record on January 2, 2002.

96. Because the North Carolina State University Library MARC record (**Appendix 1008D**) is based on the Linda Hall Library MARC record (**Appendix 1008C**), it contains the same data for essential bibliographic fields, including the Library of Congress control number in Field 010, the ISBN in Field 020, the call number in Field 090, the conference name in Field 111, the title in Field 245, three variant titles in Fields 246, publisher information in Field 260, physical description in Field 300, the title source note and the IEEE catalog number in Fields 500, the bibliographical reference and index note in Field 504, subject headings in Fields 650, and the conference sponsor in Field 710. The difference between these two records is that the North Carolina State University Library’s record reflects the latest cataloging encoding practice. For example, in Field 300 they spell out “pages” and

“illustrations,” and they include Fields 336, 337, and 338, and add URIs for the subject headings and the sponsor.

97. The North Carolina State University Library MARC record (**Appendix 1008D**) shows that their record was based on the Linda Hall Library MARC record (**Appendix 1008C**). This record was in their online catalog no later than January 2, 2002, making the conference proceedings containing *Algazi* discoverable from at least that date on. Interested users would have been able to conduct subject searches to discover this work. They would also have been able to use the ISBN, the Library of Congress control number, the conference name, the title, variant titles, the IEEE catalog number, and the sponsor to discover this work. After processing, their copy of the conference proceedings would have become publicly accessible no later than January 9, 2002.

F. Copyright Registration Record

98. **Appendix 1008E** is a true and correct copy of the copyright registration record for *Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics*. I obtained this record from the public catalog of the U.S. Copyright Office by first accessing their website at <http://www.copyright.gov/>, selecting the “Learn More” link under “Search Copyright Records,” and following the link for “Official Public Catalog (1978 to present)” under “Online Records Collections” to perform a title search to retrieve

the record. I personally located, identified and obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

99. The title, variant titles, description, and copyright claimant information in the copyright registration record match the information presented in the front matter of this conference proceedings included in **Appendix 1008A** and the Linda Hall Library copy (**Appendix 1008B**) and recorded in library records (**Appendix 1008C** and **Appendix 1008D**). The “Date of Creation” field shows this work was created in 2001, and the “Date of Publication” field shows “2001-10-21” (*i.e.*, October 21, 2001). The “Registration Number / Date” field shows “TX0005535235 / 2002-05-02” indicating this conference proceedings was registered with the Copyright Office on May 2, 2002. This record informs my opinion that the conference proceedings containing *Algazi* was published on October 21, 2001.

G. Usage Record

100. Actual usage of a publication is reflected by the papers that make reference to it. The citation history on Google Scholar shows that *Algazi* has been cited 1,671 times. **Appendix 1008F** is a list of citations from 2002 and 2003 to demonstrate early usage. Page 3 is a screen capture to show the total number of citations to *Algazi* on Google Scholar is 1,671, and Page 4 is a screen capture to show 45 citations to *Algazi* appeared from 2002 to 2003. The earliest citations are

two IEEE articles published in June and August of 2002.

H. Summary of My Opinion on *Algazi*

101. The IEEE copy of *Algazi* (**Ex. 1008**) shows it was published in 2001. The copyright registration record for the conference proceedings containing *Algazi* (**Appendix 1008E**) shows the conference proceedings was published on October 21, 2001. The Linda Hall Library MARC record (**Appendix 1008C**) shows their MARC record was completed on December 4, 2001, and the MARC record from the North Carolina State University Library (**Appendix 1008D**) shows their record was in their online catalog no later than January 2, 2002. These records and my knowledge and experience with library cataloging and processing procedures inform my opinion that the conference proceedings containing *Algazi* would have become discoverable in libraries as early as December 4, 2001, at the Linda Hall Library, and library copies would have become publicly accessible by December 11, 2001, at the Linda Hall Library, and by January 9, 2002, at the North Carolina State University Library. Citation records show the earliest publications appeared in June and August of 2002. The IEEE metadata record for *Algazi* (**Appendix 1008A**) shows the metadata record was entered into the IEEE Xplore Digital Library on August 7, 2002, making *Algazi* publicly discoverable from that date on. Because IEEE Xplore is freely accessible on the Internet, interested users would have been able to search the system to discover *Algazi*. After that, they could obtain free access to the article through an

institution with a subscription to the IEEE Xplore Digital Library, or purchase the article from IEEE themselves. In short, the records and documents I have reviewed inform my opinion that the conference proceedings containing *Algazi* would have been discoverable as early as December 4, 2001, and no later than August 7, 2002. Library copies would have become publicly accessible in December 2001 and no later than January 2002.

V. Authenticity and Public Availability of *Zhou* (Ex. 1011)

A. Authentication

102. **Ex. 1011** is a true and correct copy of “An experimental study on the role of software synthesized 3D sound in augmented reality environments” by Zhou et al. (“*Zhou*”) in *Interacting with Computers*, vol. 16, issue 5, pp. 989-1016 that I obtained from the IEEE Xplore Digital Library (IEEE Xplore) of the Institute of Electrical and Electronics Engineers (IEEE). When I began researching this article, I searched Google Scholar for records for *Zhou* and the entry for this article led me to the metadata record for this article at <https://ieeexplore.ieee.org/document/8160489> in IEEE Xplore. I followed the “PDF” link in the metadata record to obtain a copy of *Zhou*. This copy is presented as **Ex. 1011** in this Declaration.

103. **Ex. 1011** is a true and correct copy of *Zhou* obtained from IEEE Xplore, the digital library created and maintained by IEEE. Page 1 of **Ex. 1011** shows the

title, authors, and abstract of *Zhou*. The top of the page shows this article was published in “Interacting with Computers 16 (2004) 989-1016” and is available online at www.sciencedirect.com, and the journal’s website is at www.elsevier.com/locate/intcom. This page also shows the manuscript of *Zhou* was received on “19 January 2004; revised 17 April 2004; accepted 17 June 2004,” and the article was “[a]vailable online 5 August 2004.” The bottom of page 1 shows the ISSN (International Standard Serial Number) of the journal containing *Zhou* is “0953-5438” and the article doi (digital object identifier) is “10.1016/j.intcom.2004.06.014.”

104. Page 2 of **Ex. 1011** shows the article has a “2004” copyright date, and was published by Elsevier B.V. This page also shows seven author keywords for *Zhou*, including “3D sound; Augmented reality; Depth perception; Localization of sound; Task performance; Collaboration; User studies.” **Ex. 1011** shows *Zhou* has five sections, 13 figures (some in color) and 40 references.

105. The IEEE copy of *Zhou* (**Ex. 1011**) is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, the text on each page appears to flow seamlessly from one page to the next, and there are no visible alterations to the document. Moreover, **Ex. 1011** was found in the custody of a digital library owned and managed by the publisher, a

place where, if authentic, it would likely to be found. I therefore see no reason to question the authenticity of the IEEE copy of *Zhou* (**Ex. 1011**).

B. IEEE Metadata Record

106. **Appendix 1011A** is a true and correct copy of the IEEE metadata record for *Zhou* that I obtained from IEEE Xplore. I personally located, identified and obtained this metadata record. This is the type of records experts in my field would reasonably rely upon when forming their opinion. I used screenshots of the record to produce this appendix.

107. Page 1 of **Appendix 1011A** shows the metadata record for *Zhou* is available at <https://ieeexplore.ieee.org/document/8160489>. The metadata record shows the title, authors, and abstract of this article. Page 2 shows the article DOI (digital object identifier) is “10.1016/j.intcom.2004.06.014” and the article appeared in volume 16, Issue 5 (October 2004), pages 989 to 1016 of *Interacting with Computers* published by OUP. The record shows the print ISSN of this journal is 0953-5438 and the electronic ISSN is 1873-7951. It also shows seven author keywords for this article. The title, authors, abstract, journal information and author keywords match the information presented in **Ex. 1011**, confirming this record represents *Zhou*.

C. Library of Congress Copy

108. To determine the availability of *Zhou* in libraries, I searched WorldCat by “Interacting with computers” for records, and a WorldCat record at <https://worldcat.org/title/20745502> shows the Library of Congress and the University of Michigan Library are two of the holding libraries. I searched the online catalog of the Library of Congress for records for this journal, and the search result confirmed the holdings information. I then obtained a scanned copy of *Zhou* from the Library of Congress through Wisconsin TechSearch, a document delivery service based at the University of Wisconsin-Madison. This scanned copy is presented as **Appendix 1011B** in this Declaration.

109. **Appendix 1011B** is a true and correct copy of *Zhou* obtained from the Library of Congress. Page 1 shows the covers and spine of a bound volume marked as “Interacting with Computers 16 2004 QA 76.9 .H85 I59 Set 1.” Page 2 is the issue cover that shows the journal title and identifies this issue as “Volume 16, Issue 5, October 2004” and the journal’s ISSN as “0953-5438.” The cover also shows this issue is a special issue on “Physiological Computing” and was published by Elsevier. Page 3 is the issue title page. Page 4 is the copyright page that shows this issue has a “2004” copyright date and Elsevier B.V. holds the copyright right. Page 5 is the table of contents of volume 16, Issue 5 (October 2004) of *Interacting with Computers* that carries a date stamp of “Library of Congress DEC 7 2004 Copyright

Office” and shows seven articles are included in this issue and *Zhou* begins on page 989. The table of contents also shows that “Interacting with Computers is the journal of the British HCI Group, a Specialist Group of the British Computer Society.” Pages 6 to 33 (internal pages 989 to 1016) are the full text of *Zhou*. I have closely compared the Library of Congress copy of *Zhou* (**Appendix 1011B**) with the publisher’s copy obtained from IEEE (**Ex. 1011**) and found them to be identical. The only difference is that figures in **Appendix 1011B** are black and white, while some figures in **Ex. 1011** are in color.

110. **Appendix 1011B** is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, the text on each page appears to flow seamlessly from one page to the next, and there are no visible alterations to the document. Furthermore, this copy of *Zhou* was found in the custody of a national library, a place where, if authentic, it would likely be found. I therefore see no reason to question the authenticity of this copy of *Zhou*.

D. Library of Congress Records

111. **Appendix 1011C** is a true and correct copy of the bibliographic record and MARC record for *Interacting with Computers* whose vol. 16, issue 5 (October 2004) contains *Zhou*. I personally located, identified, and obtained these records from the online catalog of the Library of Congress. They are the type of records experts in my field would reasonably rely upon when forming their opinion.

112. Pages 1 to 3 of **Appendix 1011C** show the bibliographic record and holdings information of *Interacting with Computers* that contains *Zhou*. The record shows the main title of this journal, and Butterworths of Guildford, Surrey as the publisher since 1989. Notes on page 2 show Elsevier has been the publisher since 1999 and the journal is issued by the British Computer Society, Human Computer Interaction Specialist Group. The “Item Availability” area on page 3 shows the journal’s call number is “QA76.9.H85 I59” and older issues held by the library include “v.14:issue5-v.29:issue6 (2002:Oct.-2017:Nov.),” meaning vol. 16, issue 5 that contains *Zhou* is held at the Library of Congress.

113. Pages 4 to 7 of **Appendix 1011C** are the MARC record and holdings information. The first six digits of Field 008 show the MARC record was created on “891207” (*i.e.*, December 7, 1989), and the code of “c19899999” after the record creation date indicates this publication is a continuing resource that began publication in 1989 and has no end date of publication yet. Subfield |a of Field 040 shows the record was originally created by “DLC.” According to the *Directory of OCLC Members* (<https://www.oclc.org/en/contacts/libraries.html>), “DLC” is the OCLC symbol for the Library of Congress. Subfield |a of Field 042 shows that this record is verified and authenticated by “pcc” (Program for Cooperative Cataloging of the Library of Congress) and “nsdp” (National Serials Data Program). Field 022 shows the ISSN of this journal is “0953-5438,” which is the same as the ISSN on

the issue cover of **Appendix 1011B**. Field 245 shows the journal title, Field 260 shows Butterworths was the publisher from 1989 on, Field 362 shows the journal began publication with vol. 1, no. 1 in April 1989, and Field 321 shows the publication frequency since 1999 has been “[s]ix no. a year.” Field 530 shows the journal is also issued as an online journal. Field 710 shows the British Computer Society, Human Computer Interaction Specialist Group is included in the MARC record to help users discover this journal.

114. Subjects of this journal are represented in Field 050 by a Library of Congress Classification (LCC) number of “QA76.9.H85,” which represents “Human-computer interaction” in computer science, and in Field 082 by a Dewey Decimal Classification (DDC) number of “004.019,” which represents “Psychological principles” in computer science. Subject is also represented by a Library of Congress subject heading in Field 650, with “Human-computer interaction” as the main heading, followed by “Periodicals” as a form subheading encoded in subfield “v” (“|v”) to indicate the topic is treated in a journal. These subject representations in the MARC record enable users to conduct subject searches to discover this journal.

115. This MARC record shows that *Interacting with Computers* is a long-running journal, and the MARC record has made the journal discoverable at the online catalog of the Library of Congress since December 1989. Users would have

been able to conduct subject searches by the LCC and DDC numbers and by the Library of Congress subject heading to discover this journal. They would also have been able to search for the journal by title, ISSN and the British Computer Society, Human Computer Interaction Specialist Group.

116. The Library of Congress copy of *Zhou* (**Appendix 1011B**) shows a date stamp of “DEC 7 2004.” The date stamp has the appearance and distinctive characteristics of a typical check-in date stamp utilized by the library. As discussed earlier, libraries usually create one record for an entire journal, instead of creating records for individual issues of a journal, and they rely on a serial check-in system to monitor the receipt of new issues and update holdings information for users. Because journals publish latest research, the customary practice of libraries is to make a newly received issue available soon after serial check-in, usually within a week. At the Library of Congress, this would mean the newly checked-in issue would be placed in the Newspaper and Current Periodical Reading Room for easy user access soon after the serial check-in process is completed. It is therefore my opinion that the issue containing *Zhou* would have been publicly accessible by December 14, 2004, at the Library of Congress.

E. University of Michigan Library Copy

117. As evidence that *Zhou* was publicly accessible in more than one library, I searched WorldCat by the journal title for records and identified the University of

Michigan Library as another holding library. I searched their online catalog for records for the journal, and the search result confirmed the holdings information. I then obtained a copy of *Zhou* from the University of Michigan Library via Wisconsin TechSearch, a document delivery service based at the University of Wisconsin-Madison. This copy is presented as **Appendix 1011D** in this Declaration.

118. **Appendix 1011D** is a true and correct copy of *Zhou*. Page 1 is the cover that shows the issue is volume 16, issue 5 (October 2004) of *Interacting with Computers* published by Elsevier, and the issue carries a date stamp of “University of Michigan DEC 02 2004 Michigan AAE Library.” Page 2 is the issue title page and it carries the same date stamp. Page 3 is the copyright page, page 4 is the table of contents, and pages 5 to 32 (internal pages [989] to 1016) are the full text of *Zhou*. I have closely compared the University of Michigan Library copy of *Zhou* (**Appendix 1011D**) with the publisher’s copy obtained from IEEE (**Ex. 1011**) and the Library of Congress copy (**Appendix 1011B**), and concluded that these three copies have the same full text of *Zhou*, and that the front matter in the University of Michigan Library copy is the same as the front matter in the Library of Congress copy. The only difference is the Library of Congress copy includes the covers of the bound volume, a color cover and a table of contents from the back of the issue.

119. **Appendix 1011D** is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, the text

on each page appears to flow seamlessly from one page to the next, and there are no visible alterations to the document. Furthermore, this copy of *Zhou* was found in the custody of an academic library, a place where, if authentic, it would likely be found. I therefore see no reason to question the authenticity of this copy of *Zhou*.

F. University of Michigan Library Records

120. **Appendix 1011E** is a true and correct copy of the bibliographic record and MARC record for *Interacting with Computers* whose vol. 16, issue 5 (October 2004) contains *Zhou*. I personally searched for records for this journal by its ISSN and located, identified, and obtained these records from the online catalog of the University of Michigan Library. They are the type of records experts in my field would reasonably rely upon when forming their opinion.

121. Pages 1 to 3 of **Appendix 1011E** are the bibliographic record that shows *Interacting with Computers* is a journal published by Butterworths since 1989, and its ISSN is “0953-5438.” The “Available at” area shows this journal is available as an online resource and at the HathiTrust Digital Library. In addition, the University of Michigan Library has 17 items in their “offsite shelving” and page 5 shows “v.16 2004” is “On shelf” and its call number is QA 76.9 .H85 I591.

122. Pages 4 to 7 are the MARC record for this journal. The first six digits of Field 008 of the MARC record (**Appendix 1011E**) show the record was created on “911021” (*i.e.*, October 21, 1991) at the University of Michigan Library, and the

“c19899999” code following the record creation date indicates this journal is a continuing resource that began publication in 1989 and has no publication end date yet. Subfield “a” of Field 040 shows “DLC” (*i.e.*, Library of Congress) created the original MARC record. Data from Field 008 and Field 040 inform my opinion that the University of Michigan Library used the MARC record created by the Library of Congress to create their copy cataloging record on October 21, 1991, making this journal discoverable in their online catalog from that date on.

123. Because the University of Michigan MARC record is based on the Library of Congress record, except for fields with data specific to each library, the two records contain the same data in essential fields, including the Library of Congress control number in Field 010, the ISSN in Field 022, the original MARC record creator in Field 040, the Library of Congress Classification number in Field 050, the abbreviated key title for the journal in Field 210, key title in Field 222, main title in Field 245, publisher information in Field 260, physical description in Field 300, beginning numeric and chronological designations in Field 362, the title source note in Field 500, issuing body note in Field 550, Library of Congress subject heading in Field 650 and issuing body in Field 710.

124. This MARC record shows that *Interacting with Computer* is a long-running journal, and the MARC record has made the journal discoverable at the online catalog of the University of Michigan Library since 1991. Users would have

been able to conduct subject searches to discover this journal. They would also have been able to search for the journal by title, ISSN, and the issuing body.

125. The University of Michigan copy of *Zhou* (**Appendix 1011D**) shows a date stamp of “DEC 02 2004.” The stamp has the appearance and distinctive characteristics of a typical check-in date stamp utilized by the library. As discussed earlier, libraries usually create one record for an entire journal, instead of creating records for individual issues of a journal, and they rely on a serial check-in system to monitor the receipt of new issues and update holdings information for users. Because journals publish latest research, the customary practice of academic libraries is to make a newly received issue available soon after serial check-in, usually within a week. It is therefore my opinion that the University of Michigan Library copy of the journal issue containing *Zhou* would have been publicly accessible by December 9, 2004.

G. Usage Record

126. Actual usage of an article is reflected by other publications that make reference to it. The citation history of Google Scholar shows *Zhou* was cited 26 times. Page 1 of **Appendix 1011F** is a list I compiled from Google Scholar that includes citations from 2006 and 2010 to demonstrate early usage. Page 2 is a screen capture to show *Zhou* has been cited 26 times, page 3 is a screen capture to show

four citations to *Zhou* in 2006, and page 4 is a screen capture to show three citations to *Zhou* in 2010. The earliest citation appeared in October 2006.

H. Summary of My Opinion on *Zhou*

127. The publisher's copy of *Zhou* obtained from IEEE (**Ex. 1011**) shows the manuscript was accepted for publication on June 17, 2004, the article became available online on August 5, 2004, and the print copy appeared in vol. 16, issue 5 of *Interacting with Computers* that has "October 2004" as its issue date. The date stamps on the Library of Congress copy of *Zhou* (**Appendix 1011B**) and the University of Michigan copy of *Zhou* (**Appendix 1011D**) show the journal issue containing *Zhou* were received by the Library of Congress on December 7, 2004, and by the University of Michigan Library on December 2, 2004. It is therefore my opinion that these two copies would have become publicly accessible by December 14, 2004, at the Library of Congress, and by December 9, 2004, at the University of Michigan Library. MARC records of these two libraries show the journal containing *Zhou* has been discoverable in the library catalogs of these two libraries since 1989 and 1991, respectively. Citation history shows at least four citations to *Zhou* appeared in 2006 and the earliest citation appeared in October 2006.

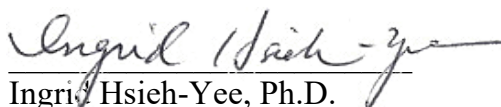
VI. Conclusion

128. In signing this declaration, I recognize that the declaration will be filed as evidence in a Petition for *Inter Partes* Review before the Patent Trial and Appeal

Board of the United States Patent and Trademark Office. I also recognize that I may be subject to deposition in the case. If deposition is required of me, I will appear at a reasonable time and place to be agreed upon.

129. All statements made herein of my own knowledge are true, and all statements made on information and belief are believed to be true. Further, I am aware that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001. I declare under penalty of perjury that the foregoing is true and correct.

Executed on June 5, 2023 in Burbank, California


Ingrid Hsieh-Yee, Ph.D.

APPENDIX

1005A

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RESEARCH-ARTICLE

Compensating for Distance Compression in Audiovisual Virtual Environments Using Incongruence

Authors: Daniel J. Finnegan, Eamonn O'Neill, Michael J. Proulx [Authors Info & Claims](#)

CHI '16: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems • May 2016 • Pages 200–212 • <https://doi.org/10.1145/2858036.2858065>

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A corrigendum was issued for this article on February 6, 2020. You can download the corrigendum from the supplemental material section of this citation page.

ABSTRACT

A key requirement for a sense of presence in Virtual Environments (VEs) is for a user to perceive space as naturally as possible. One critical aspect is distance perception. When judging distances, compression is a phenomenon where humans tend to underestimate the distance between themselves and target objects (termed egocentric or absolute compression), and between other objects (exocentric or relative compression). Results of studies in virtual worlds rendered through head mounted displays are striking, demonstrating significant distance compression error. Distance compression is a multisensory phenomenon, where both audio and visual stimuli are often compressed with respect to their distances from the observer. In this paper, we propose and test a method for reducing crossmodal distance compression in VEs. We report an empirical evaluation of our method via a study of 3D spatial perception within a virtual reality (VR) head mounted display. Applying our method resulted in more accurate distance perception in a VE at longer range, and suggests a modification that could adaptively compensate for distance compression at both shorter and longer ranges. Our results have a significant and intriguing implication for designers of VEs: an incongruent audiovisual display, i.e. where the audio and visual information is intentionally misaligned, may lead to better spatial perception of a virtual scene.



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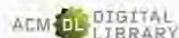
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The CHI 2016 conference includes two days of focused workshops and four days of technical content, including CHI's prestigious technical program, with 16 parallel sessions of rigorously reviewed research Papers, engaging Panels, Case Studies and Special Interest Groups (SIGs). Conference highlights also include student research, design, and game competitions, and last-minute SIGs for discussing current topics. The popular alt.chi forum enters its eleventh year of provocation within the HCI community. The conference also showcases Interactivity and Interactivity Research Demos, which are hands-on demonstrations of the best in technology and innovation. And we're particularly proud this year to include documents from our new Art Exhibition, held at the *Works/San Jose Gallery* in conjunction with the CHI conference.

We began our conference planning process with three core ideas: “**CHI in Silicon Valley**”: emphasizing local engagement in this vibrant community, “**#chiforgood**”: HCI in the community, both during the workshop time and at appropriate points during the conference, and a “**More Humane Conference and Planning Process**”: lots of transparency, early planning, no surprises, data-driven decisions and taking into account the importance of families, work/life balance, and the like.

From this, the overall theme of the conference emerged, **#chi4good**: addressing issues of social good through the innovation and creativity of the CHI community. To this end we held a Day of Service on the Saturday before the conference with hundreds of CHI attendees working on projects for non-profit and area arts organizations, and we have continued that theme throughout the conference by hosting the Diversity and Inclusion Lunch, brought childcare back to the conference for the first time in many years, and introduced the lunch@chi program to facilitate small group lunches on the first day of the conference. We've introduced CHI's first Diversity & Inclusion Statement, and our keynote speakers, represent the vibrancy, diversity and excitement of the wide field of HCI with particular emphasis on #chi4good. This year's speakers were chosen from among crowd-sourced suggestions from the CHI community and they are: Dayo Olopade, (Journalist and author of *The Bright Continent*); Kimberly Bryant (Founder, Black Girls Code), in conversation with Sarah Guthals, (Co-Founder of ThoughtSTEM); Marissa Meyer (President & CEO of Yahoo), in conversation with Terry Winograd (Professor Emeritus, Stanford University); Vishal Sikka (CEO of Infosys), in conversation with computing pioneer Alan Kay (Viewpoints Research Institute); and Salman Khan (founder, Khan Academy).

With careful consultation from the community, we have enhanced the CHI conference experience from submission and review processes, to more participation possibilities at the conference. Peer-reviewed papers have more space for references and will receive a wider range of better-matched reviews. There are more curated venues and more input into the selection of keynote speakers.

We are deeply indebted to an enormous number of volunteers, without whom CHI 2016 would not be possible, including over 4000 reviewers, 222 senior members of the program committee, nearly 100 members of the CHI 2016 conference organization committee and, of course, the more than 180 student volunteers.

The CHI conference is supported by the efforts of SIGCHI, (the Special Interest Group on Computer-Human Interaction) of the Association for Computing Machinery (ACM) and the ACM, and we are indebted for their ongoing support, organization, and leadership into the future.

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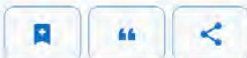


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Begault, Durand R.
(NASA Ames Research Center Moffett Field, CA United States)
Trejo, Leonard J.

Date Acquired September 7, 2013

Publication Date
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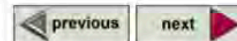
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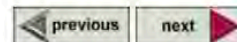
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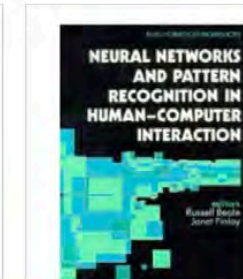
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Published in: [Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics \(Cat. No.01TH8575\)](#)

Date of Conference: 24-24 October 2001 **INSPEC Accession Number:** 7268180

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1. INTRODUCTION

Head-related transfer functions (HRTFs) capture the sound localization cues created by the scattering of incident sound waves by the body, and play a central role in spatial audio systems. Most HRTF-based commercial systems convolve the input signal with a single, "standard" head-related impulse response. Previous studies have employed the public-domain dataset for the KEMAR dummy head. It is well known that HRTFs vary significantly from person to person, and that serious perceptual distortions can result from using a single HRTF for all listeners.

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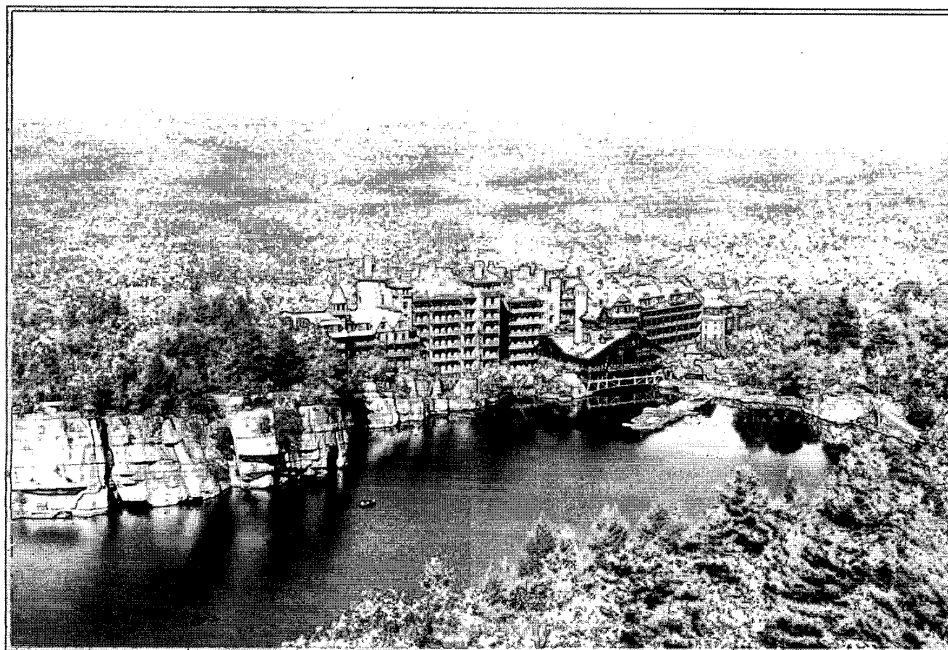
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WASPAA 2001 Workshop Program

Sunday, October 21, 2001

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APPENDIX

1008B

THE CIPIC HRTF DATABASE

V. R. Algazi, R. O. Duda and D. M. Thompson

CIPIC
U.C. Davis
Davis, CA 95616, USA
algazi@ece.ucdavis.edu

C. Avendano

Creative Advanced Technology Center
1500 Green Hills Road
Scotts Valley, CA 95066
carlosa@atc.creative.com

ABSTRACT

This paper describes a public-domain database of high-spatial-resolution head-related transfer functions measured at the U. C. Davis CIPIC Interface Laboratory. Release 1.0 includes head-related impulse responses for 45 subjects at 25 different azimuths and 50 different elevations (1250 directions) at approximately 5° angular increments. In addition, the database contains anthropometric measurements for each subject. Statistics of anthropometric parameters and correlations between anthropometry and some temporal and spectral features of the HRTFs are reported.

1. INTRODUCTION

Head-related transfer functions (HRTFs) capture the sound localization cues created by the scattering of incident sound waves by the body, and play a central role in spatial audio systems. Most HRTF-based commercial systems convolve the input signal with a single, "standard" head-related impulse response (HRIR), and several studies have employed the public-domain dataset for the KEMAR mannequin [1]. However, it is well known that HRTFs vary significantly from person to person, and that serious perceptual distortions (particularly front/back confusion and elevation errors) can occur when one listens to sounds spatialized with a non-individualized HRTF [2].

Although the determination of individual HRTFs can be addressed in a number of ways, most recently by numerical computations based on a detailed geometric mesh of the human body [3, 4], the study of individual variations requires a database of uniformly measured HRTFs. Several laboratories have developed HRTF databases to support their own research (e.g., [5]). However, the only publicly available database is the AUDIS catalog [6], which is limited to 12 subjects measured at approximately 120 positions in space, and cannot be used for commercial purposes.

The CIPIC Interface Laboratory at U.C. Davis has measured HRTFs at high spatial resolution for more than 90 subjects. Release 1.0 — a public-domain subset for 45 subjects (including KEMAR with large and with small pinnae) — is available by downloading from our web site (<http://interface.cipic.ucdavis.edu>). In addition to including impulse responses for 1250 directions for each ear of each subject, the database includes a set of anthropometric measurements that can be used for scaling studies. This paper describes the content of the database, and briefly describes the characteristics of the data. Additional technical documentation and MATLABTM utility programs for inspecting the data are provided with the database files.

2. MEASUREMENTS

Excluding the KEMAR mannequin, the 43 human subjects (27 men and 16 women) were either U.C. Davis students or visitors to the CIPIC Interface Laboratory. All HRTFs were measured with the subject seated at the center of a 1-m radius hoop whose axis was aligned with the subject's interaural axis. The position of the subject's head was not constrained, but the subject could monitor his or her head position [7].¹

Bose AcoustimassTM loudspeakers (5.8-cm cone diameter) were mounted at various positions along the hoop. A modified SnapshotTM system from Crystal River Engineering generated Golay-code signals. The subject's ear canals were blocked, and Etymotic Research ER-7C probe microphones were used to pick up the Golay-code signals. The microphone outputs were digitized at 44.1-kHz, 16-bit resolution and processed by Snapshot's oneshot function to yield a raw HRIR. A modified Hanning window was applied to the raw HRIR measurements to remove room reflections, and the results were free-field compensated to correct for the spectral characteristics of the transducers.² The length of each HRIR is 200 samples, corresponding to a duration of about 4.5 ms.

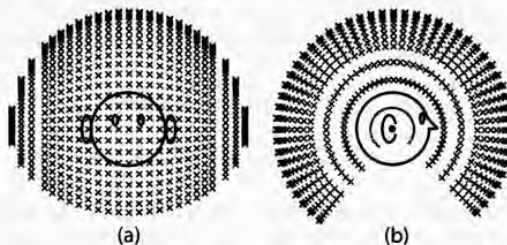


Figure 1: Locations of data points (a) front (b) side

Sound source location was specified by the azimuth angle θ and elevation angle ϕ in interaural-polar coordinates.³ Elevations

¹Small head motion, detected by abrupt changes in ITD, commonly occurred. Data sets were discarded if significant spectral discontinuities were observed.

²The free-field response was measured at the position of the center of the head. The free-field compensation was limited to 15 dB so as to control the duration and the ripples of the compensated response. In listening tests, Møller's procedure was used to compensate for headphones and to re-introduce the missing ear-canal resonance [12].

³Readers who are more familiar with vertical-polar coordinates should be warned that interaural-polar azimuth is limited to the range from -90° to $+90^\circ$. Points that are in back of the subject are found at 180° elevation.

were uniformly sampled in $360/64 = 5.625^\circ$ steps from -45° to $+230.625^\circ$. To obtain roughly uniform density on the sphere, azimuths were sampled at -80° , -65° , -55° , from -45° to 45° in steps of 5° , at 55° , 65° , and 80° . This leads to spatial sampling at 1250 points, as illustrated in Fig. 1.

3. ANTHROPOMETRY

Although the exact HRTF is complicated, its general behavior can be estimated from fairly simple geometric models of the torso, head and pinnae [8, 9, 10]. These models can be individualized to particular listeners if appropriate anthropometric measurements are available [11]. However, specifying a general set of well-defined and relevant measurements is problematic. The problem is particularly difficult for the pinna, where small variations can produce large changes in the HRTF. Anthropometric measurements, even if imperfect, enable the investigation of possible correspondences or correlations between physical dimensions and HRTF features.

The choice of anthropometry relevant to understanding or estimating HRTFs lead us to follow an approach proposed by Genuit [8], and to define a set of 27 anthropometric measurements — 17 for the head and torso (Fig. 2) and 10 for the pinna (Fig. 3).⁴

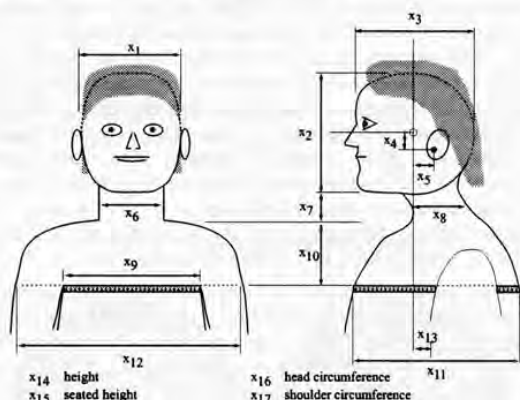


Figure 2: Head and torso measurements

The range of variation for the individuals in the CIPIC database can be measured by some statistics for the anthropometric measurements. In general, histograms of the individual measurements indicate a basically normal distribution of values. The means and standard deviations for the anthropometric parameters are listed in Table 1.⁵ Here distances are measured in cm and angles in degrees, and the percentage variation is $2\sigma/\mu$ in percent. For example, the mean head width was 14.49 cm, and, assuming a normal distribution, 95% of the cases were within $\pm 13\%$ of the mean. Excluding the offset measurements x_4 , x_5 and x_{13} , for which percentage deviation is not meaningful, we see that the average percentage de-

⁴In general, a particular measurement was included if (a) it was deemed to have a significant influence on the HRTF, and (b) it could be reliably and reasonably easily measured. In addition we recorded each subject's weight, age and sex as possibly relevant.

⁵Although the number of subjects in the database is too small to be representative of the general population, our results are in general agreement with published values for adults [13].

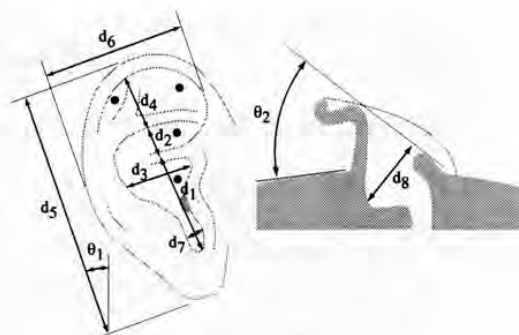


Figure 3: Pinna measurements

viation is $\pm 26\%$. Thus, there is considerable variation in the sizes and shapes of the subjects in the database.

Var	Measurement	μ	σ	%
x_1	head width	14.49	0.95	13
x_2	head height	21.46	1.24	12
x_3	head depth	19.96	1.29	13
x_4	pinna offset down	3.03	0.66	43
x_5	pinna offset back	0.46	0.59	254
x_6	neck width	11.68	1.11	19
x_7	neck height	6.26	1.69	54
x_8	neck depth	10.52	1.22	23
x_9	torso top width	31.50	3.19	20
x_{10}	torso top height	13.42	1.85	28
x_{11}	torso top depth	23.84	2.95	25
x_{12}	shoulder width	45.90	3.78	16
x_{13}	head offset forward	3.03	2.29	151
x_{14}	height	172.43	11.61	13
x_{15}	seated height	88.83	5.53	12
x_{16}	head circumference	57.33	2.47	9
x_{17}	shoulder circumference	109.43	10.30	19
d_1	cavum concha height	1.91	0.18	19
d_2	cyma concha height	0.68	0.12	35
d_3	cavum concha width	1.58	0.28	35
d_4	fossa height	1.51	0.33	44
d_5	pinna height	6.41	0.51	16
d_6	pinna width	2.92	0.27	18
d_7	intertragal incisure width	0.53	0.14	51
d_8	cavum concha depth	1.02	0.16	32
θ_1	pinna rotation angle	24.01	6.59	55
θ_2	pinna flare angle	28.53	6.70	47

Table 1. Anthropometric statistics, % = $100(2\sigma/\mu)$

Correlations between these measurements may be of interest, since one might conjecture that a subject with a large head would also have large pinnae. Indeed, this is the basic assumption behind Middlebrooks's procedure for scaling HRTFs to account for changes in body size [14]. In general, there are statistically significant but weak correlations between most pairs of measurements.⁶ Scatterplots and correlation coefficients ρ for four interesting examples are shown in Fig. 4.

We focus on the important but difficult to measure pinna di-

⁶For 45 subjects, any magnitude of more than .28 is statistically significant at the 95% confidence level.

mensions. Fig. 4a shows that there is a fairly good correlation between pinna height and cavum concha height ($\rho = 0.45$). There is also some correlation between head depth and cavum concha width (Fig. 4b, $\rho = 0.33$). Interestingly, there is not much correlation between these two concha dimensions (Fig. 4c, $\rho = 0.25$). Perhaps more surprising, there is little correlation between head height and pinna height (Fig. 4d, $\rho = 0.16$), and about the same correlation between head height and cavum concha height $\rho = 0.17$. In general, there appears to be relatively little correlation between the sizes of large and small anatomical features, and accurate estimation of pinna dimensions from head and torso measurements is problematic.

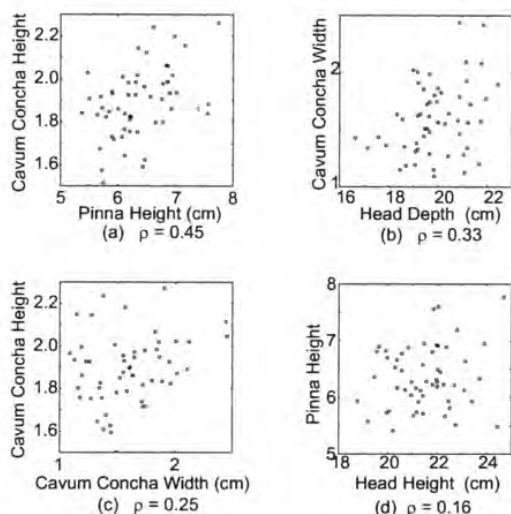


Figure 4: Selected scatterplots

4. HRTF VARIATION

One of the advantages of measuring HRTF data at high spatial resolution is that the data can be represented as an image. Fig. 5a shows such an image representation of the impulse response for KEMAR's right ear. Each column in this image is one impulse response at a particular azimuth,⁷ with brightness coding the strength of the response. The variation of arrival time with azimuth is clearly seen in the roughly sinusoidal shape of the top envelope of the response. The weakening of the response as the azimuth approaches the opposite side of the head shows the effect of head shadow.

Fig. 5b shows the spectrum for this same case. Here each column is the magnitude of the HRTF in dB, after the power spectrum was smoothed by a constant- Q filter ($Q = 8$). The generally darker appearance of the right half of the image shows the effect of head shadow. The strong response on the ipsilateral side around 5 kHz corresponds to the quarter-wavelength depth resonance identified by Shaw [9], and the weak response around 9 kHz is the so-called "pinna notch." In addition, other interesting but

⁷Of course, interaural-polar azimuth must lie between -90° and $+90^\circ$. For convenience, we show the conventional vertical-polar azimuth in this figure.

more difficult to explain azimuth-dependent spectral features can be seen.

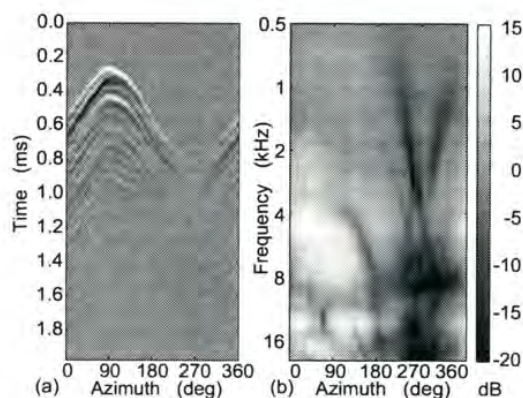


Figure 5: Horizontal plane (a) HRIR (b) HRTF

These images give some idea of the HRTF variability for a single subject. It is more difficult to characterize the range of HRTF variability between subjects. However, two simple measures — the maximum interaural time difference ITD_{max} and the pinna-notch frequency f_{pn} — are simple, perceptually relevant parameters that characterize the variability that exists.

For the subjects in the database, ITD_{max} is approximately normally distributed, with $\mu = 646 \mu\text{sec}$ and $\sigma = 33 \mu\text{sec}$, which corresponds to a $\pm 10.3\%$ variation. Not surprisingly, ITD_{max} is strongly correlated with head size (see Fig. 6), and it can be estimated quite accurately using simple linear regression. The best single predictor is the head width, with a correlation coefficient of $\rho = 0.78$ between the estimated and the actual ITD . The best pair are the head width and the head depth, for which $\rho = 0.87$. For a more detailed presentation of the estimation of ITD from anthropometry, see [11].

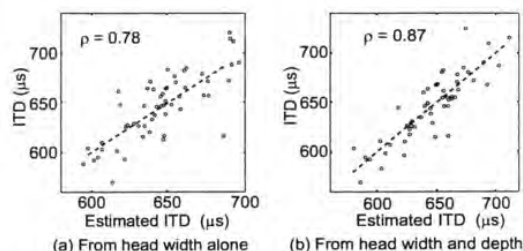


Figure 6: Scatterplots for estimation of the ITD

In the frequency-domain, most HRTFs exhibit the prominent depth resonance around 3 to 4 kHz, followed by the pinna "notch" [9]. Fig. 7 shows the HRTF magnitudes for $\theta = \phi = 0^\circ$ for a set of 54 subjects.⁸ The pinna notches are indicated by the black dots, and the graphs are sorted by the pinna-notch frequency f_{pn} .

⁸Some subjects used to evaluate statistics have not been included in the database release.

Statistically, f_{pn} is approximately normally distributed, with $\mu = 7600$ Hz and $\sigma = 1050$ Hz, which corresponds to a rather large $\pm 28\%$ variation. As expected, f_{pn} is correlated with the pinna measurements, but the relationship is not strong, and linear regression is not as successful in estimating f_{pn} from anthropometry. The best single predictor of f_{pn} is the cavum concha height ($\rho = 0.33$). Somewhat surprisingly, the best pair of predictors are the two angles θ_1 and θ_2 ($\rho = 0.42$), and the best triple adds to these the fossa height ($\rho = 0.51$). These results reflect the fact that the scattering of incident waves by the pinna is a complex process related to detailed features, and that accurate estimation of f_{pn} may well require additional concha parameters not included in our measurements. However, simple regression analysis does help identify the most significant of the measured parameters or indicates the need for additional measurements. It our view that the effective customization of HRTFs will requires a deeper understanding of the perceptually important characteristics of the HRTF and of their dependence on detailed pinna features.⁹

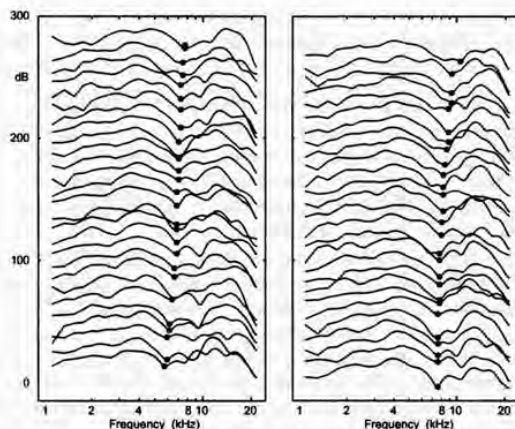


Figure 7: HRTF magnitudes for $\theta = \phi = 0^\circ$

5. CONCLUSIONS

High-spatial-resolution HRTF measurements clarify the physical sources of HRTF behavior. A uniform database of HRTFs enables the study of person-to-person differences and of the relation of temporal and spectral characteristics of the HRTF to the anthropometric data. We hope that public availability of the CIPIC HRTF database, augmented with anthropometric measurements, will facilitate further research in the understanding, modeling, and use of individualized HRTFs.

6. ACKNOWLEDGMENTS

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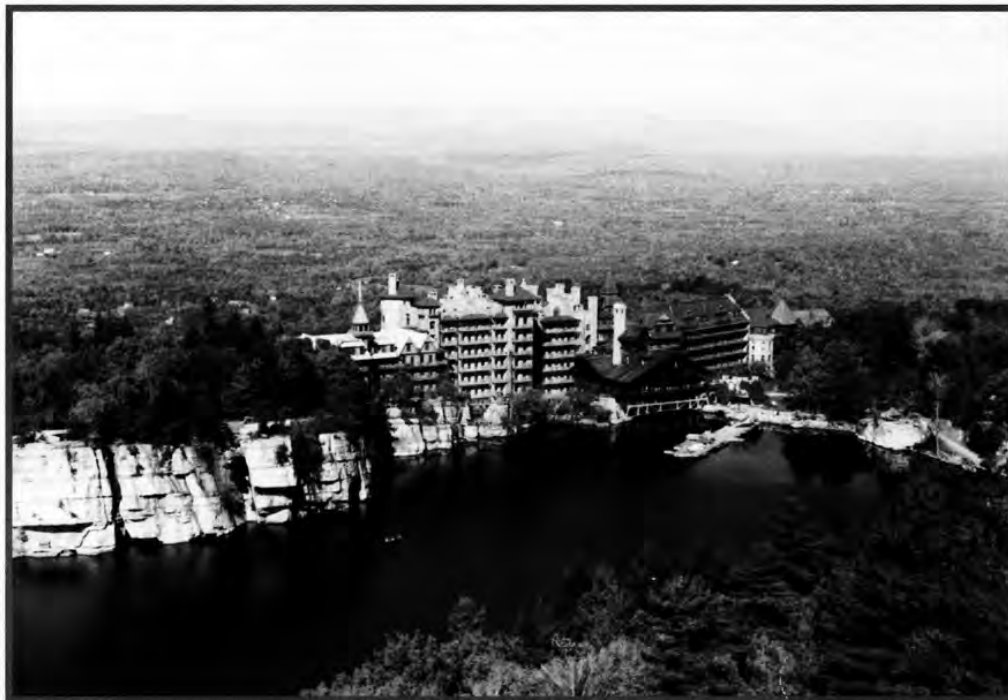
⁹This area of research would benefit from systematic parametric studies using geometric models and computational techniques [3, 4].

Semiconductor, Creative Advanced Technology Center, Hewlett-Packard, and Interval Research Corporation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or our other sponsors.

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Mohonk Mountain House
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2001 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics

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The members of the organizing committee are pleased to welcome you to the 2001 Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA), sponsored by the IEEE Signal Processing Society.

The primary objective of this two-and-a-half day workshop is to provide an informal environment for the discussion of research problems in audio and acoustics and the signal processing techniques applied to those problems. More than 90 paper submissions were received for this year's workshop and after a careful review process, 56 papers were accepted. Unfortunately, many worthy papers could not be accepted due to the limited presentation time at the workshop. In addition to the paper presentations, two invited speakers will be giving keynote addresses: Robert Moog (opening keynote on Sunday evening) and Scott Douglas (Tuesday afternoon).

The papers are organized into sessions on the following topics: Musical Analysis I and II, Hearing Aids, Signal Analysis, Localization, Source Analysis and Separation, Perception, Compression, Arrays, Spatial Sound Synthesis, Audio Modification, and New Ideas. Technical sessions are scheduled in the morning and before and after dinner; the afternoons have been left free for outdoor activities or informal meetings among the workshop participants.

As you can see from the program, there is a great deal of exciting new activity in the area of signal processing for audio and acoustics. We encourage you to attend the workshop not only to listen to these technical presentations, but also to meet friends, make new acquaintances, and enjoy the beauty of the Mohonk environment. Thank you for your participation.

GENERAL INFORMATION

In keeping with tradition, this event is being held at the Mohonk Mountain House, New Paltz, New York, in the Shawangunk Mountain region of New York, an area known for its outstanding beauty. The early autumn, when foliage is near peak, is an especially attractive time for hiking and other outdoor activities. The hotel is on the shore of Mohonk Lake (elevation 1253 feet), about 90 miles north of New York City. It is a popular destination for people escaping the city to enjoy the hilly and forested surroundings. Guests can wander through Mohonk's 2000 wooded acres at will, and the Catskill Mountains are close by for further exploration. More information on the Mohonk resort and services can be found at www.mohonk.com.

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WASPAA 2001 Workshop Program

Sunday, October 21, 2001

KEYNOTE ADDRESS

8:00 PM – 10:00 PM

Keynote Speaker: Robert Moog, Big Briar, Inc., Asheville, NC, USA

Monday, October 22, 2001

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8:00 AM – 9:50 AM

Chair: Daniel P. W. Ellis, Columbia University, New York, NY, USA

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