UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

META PLATFORMS, INC.,
Petitioner,

v.

MULLEN INDUSTRIES LLC,
Patent Owner.

Case IPR2025-00740
U.S. Patent No. 10,828,559 B2
Issue Date: November 10, 2020

Title: LOCATION-BASED GAMES AND AUGMENTED REALITY SYSTEMS

DECLARATION OF INGRID HSIEH-YEE, PH.D.

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I, Ingrid Hsieh-Yee, declare as follows:

I. INTRODUCTION AND QUALIFICATIONS

1. I am over the age of eighteen and otherwise competent to make this declaration.

2. I have been retained by counsel for Petitioner to provide my expert opinion in connection with the above-captioned proceeding ("IPR") regarding the public availability of a certain prior art references in relation to U.S. Patent No. 10,828,559 B2 ("Challenged Patent").

3. I am being compensated for my time in connection with this IPR at my current consulting 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 (**Appendix A**). The following is a brief summary of my relevant qualifications and professional experience.

5. I was a professor in the Department of Library and Information Science at the Catholic University of America for 32 years and was conferred the title of Professor Emerita in December 2022. I have experience working in an academic

library, a medical library, and a legislative library. I hold a Ph.D. 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

II. BACKGROUND OF LIBRARY CATALOGING

A. Machine-Readable Cataloging ("MARC")

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

8. 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 B** is a true and correct copy of Parts VII to X of "Understanding MARC Bibliographic: Machine-Readable Cataloging" (https://www.loc.gov/marc/umb/um07to10.html), a brief description and tutorial published by the Library of Congress in 2009 that explains commonly used MARC fields. For example, the personal author of a 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. More details of MARC21 format for Bibliographic Data are available on the Library of Congress website at https://www.loc.gov/marc/bibliographic/.

9. I am very familiar with library cataloging and processing practices and the relationships between OCLC (Online Computer Library Center) and library catalogs, and how libraries create and share their records to help the public discover

and access information.

10. OCLC is the largest bibliographic network of the world, and its WorldCat database contains more than 559 million records from thousands of member institutions (many of which are libraries of some type) in more than 100 countries. OCLC was founded in 1967 to promote and support library cooperation. According to the third article of the "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).

11. 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).

12. After a MARC record is created in Connexion, it also becomes searchable and viewable on WorldCat.org, which is a free web portal for users to explore more than 10,000 libraries worldwide. Records in WorldCat.org, 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.

B. Library Online Catalogs

13. 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 nowadays 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.

14. 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 the OCLC WorldCat database 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.

15. I am 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:

- Google Scholar (https://scholar.google.com/)
- Libraries.org, a directory of libraries throughout the world (https://librarytechnology.org/libraries/)
- Online catalog of the Linda Hall Library (https://catalog.lindahall.org/discovery/search?vid=01LINDAHALL_INST:LHL)
- Public catalog of the US Copyright Office (https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?DB=local&PAGE=First)
- WorldCat.org (https://search.worldcat.org/)

C. Scope of this Declaration

16. I have been asked to offer an opinion on the public availability dateS of the following documents:

- Rolland, J. P., Holloway, R. L., & Fuchs, H. (1995, December). Comparison of optical and video see-through, head-mounted displays, in *Telemanipulator and Telepresence Technologies : 31 October-1 November 1994, Boston, Massachusetts*, Proceedings of SPIE vol. 2351, pp. 293-307, **EX1013** ("*Rolland*").

17. I am informed by counsel and. Understand that a given reference is "published" 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 and understand that materials available in a library constitute "printed publications" if they are catalogued and indexed according to general library practices and protocols that make the references available and accessible to members of the interested public.

18. I have been informed by counsel that the Challenged Patent claims November 16, 2004, as its earliest priority date. I have assessed public accessibility of the documents referenced below as of this claimed priority date.

19. I have been informed by counsel that the subject matter of this proceeding generally relates to virtual and augmented reality computing systems.

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

21. I have been informed by counsel that a person of ordinary skill in the art as of November 16, 2004, would have knowledge of the scientific literature and have skills relating to virtual and augmented reality computing systems. A person of

ordinary skill would have possessed a bachelor's degree in electrical engineering, computer science, or similar field, with two years combined experience in designing and/or developing interactive location-based computer systems/software, such as video games or other simulations incorporating location information (such as GPS information associated with a user's physical location), and in designing and/or developing computer systems/software involving graphical virtual and/or augmented reality. A person could also have qualified as a person of ordinary skill in the art with some combination of (1) more formal education (such as a master's of science degree) and less technical experience, or (2) less formal education and more technical or professional experience.

22. It is my opinion that such a person would have been actively engaged in learning about the field, possibly through formal instruction and through bibliographic resources. By at least November 16, 2004, 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 Opinion

23. In the preparation of this declaration, I have reviewed **EX1013** referenced in paragraph 16 above, and any other documents I reference herein. Each of these is a type of material that experts in my field would reasonably rely upon when forming their opinions. I provided a further description of materials I

considered in **Appendix C**.

III. Authentication and Public Availability of *Rolland* (EX1013)

A. Authentication

24. **Exhibit 1013** is a true and correct copy of "Comparison of optical and video see-through, head-mounted displays," ("*Rolland*"), by Rolland, Holloway, and Fuchs, in *Telemanipulator and Telepresence Technologies : 31 October-1 November 1994, Boston, Massachusetts*, Proceedings of SPIE vol. 2351, pp. 293-307, that I obtained from the Linda Hall Library. This copy is presented as **EX1013** in this declaration.

25. Page 1 is the cover that shows the conference name, conference chair and editor, and the date and location of the conference. The top of the page indicates this work is the proceedings of "SPIE – The International Society for Optical Engineering" and the page identifies this work as "Volume 2351." Page 2 shows the same information as the cover, and indicates "SPIE – The International Society for Optical Engineering" sponsored and published this work, and "IEEE NCC – Virtual Reality Technical Committee" is a cooperating organization. Page 3 is the copyright page that shows this work has a "1994" copyright date and SPIE holds the copyright. It also shows the ISBN (International Standard Book Number) of this work is "0-8194-1686-X" and the Library of Congress Catalog Card No. for this work is "94-67548." The top of the page shows a hand-written call number of "TJ210.3 .T442

1994." Pages 4 to 6 (internal pages iii to v) are the table of contents, and the left side of page 4 shows an annotation of "3-14-95" (*i.e.*, March 14, 1995), indicating the Linda Hall Library added this work to their collections on this date. The knowledge of this date annotation practice is based on my personal experience with the library and its collections. This page also shows a library stamp of the Linda Hall Library. Page 6 (internal page v) shows *Rolland* begins on page 293.

26. Pages 7 to 21 are the full text of *Rolland*. Page 7 (internal page 293) shows the title, authors, abstract, and keywords of this article. The bottom of the page shows this article appears in "SPIE Vol. 2315 Telemanipulator and Telepresence Technologies (1994)" whose ISBN is "0-8194-1686-X." **EX1013** shows *Rolland* has a total of 15 pages, including seven figures and 29 references.

27. To authenticate **EX1013**, I obtained a copy of *Rolland* from the webpage for this article at https://www.spiedigitallibrary.org/conference-proceedings-of-spie/2351/0000/Comparison-of-optical-and-video-see-through-head-mounted-displays/10.1117/12.197322.short from the SPIE Digital Library. This SPIE copy is presented as **EX1013A** in this declaration. **EX1013A** shows this article has a total of 15 pages, including seven figures and 29 references. I have closely compared the library copy (**EX1013**) with the publisher copy (**EX1013A**), and found them to contain the same content for *Rolland*.

28. **EX1013** is in a condition that raises no suspicion about its authenticity.

Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, this library copy has the same content as the publisher copy (**EX1013A**) and is held by a well-known public research library. Based on my review and analysis, it is my opinion that **EX1013** is authentic.

B. Records of Linda Hall Library

29. To determine the public availability date of *Telemanipulator and Telepresence Technologies* (Proceedings of SPIE Vol. 2351) that contains *Rolland* in libraries, I obtained records for this work from the online catalog of the Linda Hall Library. **EX1013B** is a true and correct copy of the bibliographic and MARC records for this work. 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.

30. Pages 1 to 3 of **EX1013B** are the bibliographic record and Page 4 is a copy of the MARC record. Page 1 shows ”conference proceedings” is the format of this work, and it is cataloged as a book and is available at “Linda Hall Library Books – 2nd Floor (TJ210.3.T442 1994).” The record details includes the title, series title, personal and corporate contributors, subjects, ISBNs, series details, publisher, creation date (“c1994”), physical details, and a general note. The title, editor, associated organizations, publisher, the 10-digit ISBN, and series information match the information presented in **EX1013**, confirming this record represents

Telemanipulator and Telepresence Technologies that contains *Rolland*.

31. Page 4 is a copy of the MARC record. The first six digits of Field 008 show the record was created on "950214" (*i.e.*, February 14, 1995), and the code of "s1994" following the record creation date shows this work has a single publication date of 1994. Subfields 'a" and "c" of Field 040 show "RVE" created the original record and entered it into the OCLC WorldCat database, and subfield "d" shows "LHL" modified the original record later. According to the *Directory of OCLC Members* (https://www.oclc.org/en/contacts/libraries.html), "RVE" is the OCLC library symbol for the Rochester Institute of Technology Library, and "LHL" is the OCLC library symbol for Linda Hall Library. Based on the data in Fields 008 and 040, it is my opinion that the Rochester Institute of Technology Library created the original record for the conference proceedings containing *Rolland* on February 14, 1995, and Linda Hall Library used the original record to create their copy cataloging record. The date annotation in **EX1013** shows the library added the conference proceedings to their collections on March 14, 1995. It is therefore my opinion that the copy cataloging record for *Telemanipulator and Telepresence Technologies* that contains *Rolland* became discoverable in their online catalog on March 14, 1995. A customary library practice is to process a newly cataloged monograph promptly for public access, usually within a week after the cataloging work is completed. It is therefore my opinion that, after processing, the physical copy of *Telemanipulator and*

Telepresence Technologies that contains *Rolland* became publicly accessible at the Linda Hall Library by March 21, 1995.

32. Field 010 shows the Library of Congress card number, Field 020 shows the 13-digit and 10-digit ISBNs, Field 245 shows the title, subtitle, and statement of responsibility, and Field 260 shows the publisher and copyright date. Field 490 shows the series information presented in the publication and Field 830 shows the authorized form of the series title and numbering. The editor is presented in Fields 700, and two sponsoring organizations are included in Fields 710. These fields show interested users could use these data elements to discover the conference proceedings containing *Rolland*.

33. Interested users could also conduct subject searches to discover this conference proceedings, because the MARC record contains subject representations. Field 090 shows a Library of Congress Classification number ("TJ210.3") that represents "Congresses" on "Mechanical devices and figures. Automata. Ingenious mechanism. Robots (General)" (source: Library of Congress Classification Schedule T at https://www.loc.gov/aba/publications/FreeLCC/LCC_T2019TEXT.pdf), and Fields 650 show four Library of Congress subject headings, with "Manipulators (Mechanism)," "Robotics," "Remote control," and "Virtual reality" representing the main topics, each followed by "Congresses" as a form subheading encoded in subfield "v" to indicate the main topics are treated at a conference.

34. The date annotation in **EX1013** and the MARC record (**EX1013B**) show that the Linda Hall Library completed their copy cataloging record for *Telemanipulator and Telepresence Technologies* that contains *Rolland* on March 14, 1995, making this work discoverable in their online catalog from that date on. As of that date, interested users could discover this work by title, series, editor, and two sponsoring organizations. They could also conduct subject searches to discover this conference proceedings.

35. As evidence that the Linda Hall Library had an online catalog in operation in 1995 when the library added *Telemanipulator and Telepresence Technologies* that contains *Rolland* on March 14, 1995 to their collections, I obtained a profile of the library at https://librarytechnology.org/library/2294 from libraries.org, a directory of libraries throughout the world. I personally located, identified, and obtained this profile. This is the type of record experts in my field would reasonably rely upon when forming their opinions. This profile is presented as **EX1013C** in this declaration.

36. The Technology Profile on page 2 of **EX1013C** shows the Linda Hall Library began using Horizon as their online catalog in 1994, and changed to Voyager in 2010. These dates mean that in 1995 interested users were able to use the Horizon system to search for the conference proceedings containing *Rolland* and access this article at the Linda Hall Library.

C. Copyright Registration Record

37. **Ex. 1013D** is a true and correct copy of the copyright registration record for *Telemanipulator and Telepresence Technologies* that contains *Rolland*. I personally located, identified, and obtained this record from the public catalog of the US Copyright Office. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

38. The title, subtitle, editor, imprint, series title, and series numbering match the information presented in **EX1013**, confirming this record represents *Telemanipulator and Telepresence Technologies* that contains *Rolland*. The "Date of Publication" field shows this work was published on "1994-12-30" (*i.e.*, December 30, 1994), and the "Registration Number / Date" field shows this work was registered with the US Copyright Office on "1995-04-05" (*i.e.*, April 5, 1995). These dates align well with the "3-14-95" date annotation in **EX1013** that shows the Linda hall Library added this work to their collections on that date.

D. Usage Records

39. Actual usage of a publication is reflected by other publications that make reference to it. I have reviewed citations to *Rolland* on Google Scholar to compile a list of early citations. **EX1013E** presents six citations published from 1996 to 2000 to show early usage of *Rolland*. This list shows the earliest citation appeared in 1997.

E. Summary of My Opinion on *Rolland*

40. The copyright registration record for *Telemanipulator and Telepresence Technologies* that contains Rolland (**EX1013D**) shows this work was published on December 30, 1994. The date annotation on **EX1013** shows Linda Hall Library added this work to their collections on March 14, 1995, and the MARC record (**EX1013B**) shows their copy cataloging record was based on a record created by the Rochester Institute of Technology Library. The MARC record has made this work discoverable in the online catalog of the Linda Hall Library since March 14, 1995. The physical copy, after processing, would become publicly accessible by March 21, 1995.

IV. Conclusion

41. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in this proceeding. If required, I will appear for cross-examination at the appropriate time.

42. I hereby declare that all statements made herein of my own knowledge are true and that all statements are made on information and belief are believed to be true, and further that these statements were 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.

Dated: March 25, 2025

Respectfully submitted,

Ingrid Hsieh-Yee

Ingrid Hsieh-Yee, Ph.D.
Annapolis, Maryland

APPENDIX A

Ingrid Hsieh-Yee

Professor Emerita
Dept. of Library and Information Science
Catholic University of America
Washington, D.C. 20064
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Education

Ph.D. 1990. Library and Information Studies, University of Wisconsin-Madison
Minors: Sociology and Psychology

M.A. 1984. Library and Information Studies, University of Wisconsin-Madison.

M.A. 1983. Comparative Literature, University of Wisconsin-Madison.

B.A. 1980. Foreign Languages and Literature, National Taiwan University.

Work Experience

Professor, School/Dept. of Library and Information Science, Catholic University of America, 1990-2022 (Assistant Professor, 1990-1996; Associate Professor, 1997-2004; Professor 2004-2022; Professor Emerita 2022)

Co-Chair, Dept. of Library and Information Science, Catholic University of America, June 2015-August 2016.

Acting Dean, School of Library and Information Science, Catholic University of America, January 2010-June 2012.

Cataloger, Dept. of Legislative Reference Library, Annapolis, Maryland, 1989-1990.

Lecturer, School of Library and Information Studies, University of Wisconsin-Madison, 1988.

Teaching Assistant, School of Library and Information Studies, University of Wisconsin-Madison, 1986-1988.

Cataloger, Health Sciences Library, University of Wisconsin-Madison, 1984-1986.

Areas of Teaching and Research Interests

Information Organization and Access; Metadata; Cataloging & Classification; Information Architecture; Information Retrieval; Digital Collections; Social Media; Scholarly

Communication; Information Behavior; Health Informatics; Human Computer Interaction; Usability Studies

Grants & Honors

Cultural Heritage Information Management Project. IMLS grant. Amount: $498,741. Period: Aug. 2012 to July 2015. Co-PI with Dr. Youngok Choi.

D.C. Health Information Technology (HIT4): Building Capacity & Providing Access in Our Nation's Capital. Dept. of Labor H2B Training Grant. Grant amount: $4,175,500. Grant period: Nov. 2011 to Dec. 2015. Partner with the Metropolitan School of Professional Studies of the Catholic University of America, Children's National Medical Center, D.C. Department of Employment Services, Holy Cross Hospital, Howard University, Center for Urban Progress, Providence Hospital, and Sibley Memorial Hospital.

Capital Health Careers Project. Department of Labor Healthcare Sector and Other High Growth and Emerging Industries Grant. Grant amount: $4,953,999. Grant period: March 2010 – February 2013. Awarded to a group of healthcare organizations and educational institutions in Washington, D.C. Providence Health Foundation of Providence Hospital (Lead institution). Part of the grant supported the development of a Master's degree program in Information Technology with a concentration in Health Information Technology offered by the School of Library and Information Science.

The Washington D.C. School Librarians Project. IMLS grant. Grant amount: $412,660. Grant period: Aug. 2007 – June 2011. The School partnered with the District of Columbia Public Schools (DCPS) and the District of Columbia Library Association to educate and mentor school media specialists for the DCPS system. PI, Jan. 2010 to June 2011.

SIG Member of the Year, American Society for Information Science and Technology (2009).

Most Outstanding Paper of *OCLC Systems & Services* (2001).

ALISE Research Grant (2001).

Most Outstanding Paper of *OCLC Systems & Services* (2000).

Research Grant from ERIC (1999-2000).

Best Research Paper Award; Association for Library and Information Science Education (1998).

Research Grants, Catholic University of America. 1991, 1992, 1993, 1996, 1998, 1999, 2004, 2005, 2006, 2007, 2013-14.

Cooperative Faculty Research Grant, Consortium of Universities in the Washington Metropolitan Area (1993-1994).

Cooperative Research Grant, Council on Library Resources (1993-1994).

Journal of the American Society for Information Science Best Paper Award (1993).

ASIS/ISI Information Science Doctoral Dissertation Scholarship (1989).

HEA Title IIB Fellowship (Dept. of Education) (1989)

Chinese-American Librarians Association Scholarship (1987).

Beta Phi Mu (1985).

Vilas Fellowship, University of Wisconsin-Madison. 1984

Publications

Hsieh-Yee, I. (2021). Can We Trust Social Media? *Internet Reference Services Quarterly*, 1-15. Published online: 28 July, 2021. 10.1080/10875301.2021.1947433.

Bailey, T., & Hsieh-Yee, I. (2020). Combating the Sharing of False Information: History, Framework & Literacy Strategies, *Internet Reference Services Quarterly*, 24 (1-2), 9-30.

Choi, Y., and Hsieh-Yee, I. (2010). Finding Images in an OPAC: Analysis of User Queries, Subject Headings, and Description Notes. *Canadian Journal of Information and Library Science,* 34(3): 271 – 295.

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NISO Framework for Guidelines for Building Good Digital Collections. 3rd ed. Baltimore, MD: National Information Standards Organization, 2007. Also available online: http://www.niso.org/framework/framework3.pdf (NISO Working Group members: Priscilla Caplan (chair), Grace Agnew, Murtha Baca, Tony Gill, Carl Fleischhauer, Ingrid Hsieh-Yee, Jill Koelling, and Christie Stephenson.)

Choi, Y., Hsieh-Yee, I., and Kules, B. (2007). Retrieval Effectiveness of TOC and LCSH. *Proceedings of the Joint Conference on Digital Libraries*, pp. 233-234.

Vellucci, S., and Hsieh-Yee, I. (2007). They Didn't Teach Me That in Library School! Building

a Digital Teaching Commons to Enhance Metadata Teaching, Learning and Research. *Proceedings of the National Conference of the Association of College and Research Libraries, Baltimore, MD*, pp. 26-31.

Mitchell, Vanessa, and Ingrid Hsieh-Yee. (2007). Converting Ulrich's Subject Headings to FAST Headings: A Feasibility Study. *Cataloging & Classification Quarterly,* 45(1): 59-85.

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Tang, R., Hsieh-Yee, I., and Zhang, S. (2007). User Perceptions of MetaLib Combined Search: An Investigation of How Users Make Sense of Federated Searching." *Internet Reference Services Quarterly,* 12(12): 211-236.

Hsieh-Yee, I., Tang, R., and Zhang, S. (2006). User Perceptions of a Federated Search System. *Proceedings of the Joint Conference on Digital Libraries*, *June 11-15, 2006, Chapel Hill*, p. 338.

Hsieh-Yee, I. (2006). *Organizing Audiovisual and Electronic Resources for Access: A Cataloging Guide*. 2nd ed. Westport, Conn.: Libraries Unlimited.

NISO A Framework of Guidance for Building Good Digital Collections. 2nd ed. Bethesda, MD: National Information Standards Organization, 2004. Framework Advisory Group: Grace Agnew, Liz Bishoff, Priscilla Caplan (Chair), Rebecca Gunther and Ingrid Hsieh-Yee.

Hsieh-Yee, I. (2004). Cataloging and Metadata Education in North American LIS Programs. *Library Resources & Technical Services,* 48(1): 59-68.

Hsieh-Yee, I. (2004). Cataloging and Metadata Education. In Gary E. Gorman (Ed.), *International Yearbook of Library and Information Management 2003: Metadata Applications and Management*, (pp.204-234). London: Facet Publishing.

Yee, P. L., Hsieh-Yee, I., Pierce, G.R., Grome, R., and Schantz, L. (2004). Self-Evaluative Intrusive Thoughts Impede Successful Searching on the Internet. *Computers in Human Behavior,* 20(1): 85-101.

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Hsieh-Yee, I., and Smith, M. (2001). The CORC Experience: Survey of Founding Libraries, Part I. *OCLC Systems & Services,* 17: 133-140. (Received "The Most Outstanding Paper of OCLC Systems & Services in 2001" award.)

Hsieh-Yee, I., and Smith, M. (2001). The CORC Experience: Survey of Founding Libraries, Part II, Automated Tools and Usage. *OCLC Systems & Services,* 17: 166-177. (Received "The Most Outstanding Paper of OCLC Systems & Services in 2001" award.)

Hsieh-Yee, I. (2001). ERIC User Services: Changes and Evaluation for the Future. *Government Information Quarterly,* 18: 31-42.

Hsieh-Yee, Ingrid. (2001). Research on Web Search Behavior. *Library and Information Science Research,* 23: 167-185.

Logan, E., and Hsieh-Yee, I. (2001). Library and Information Science Education in the Nineties. *Annual Review of Information Science and Technology,* 35: 425-477.

Hsieh-Yee, I. (Ed.) (2001). *Library and Information Science Research*, 23 (2). A special issue in honor of the retirement of Douglas L. Zweizig.

Hsieh-Yee, I. (2000). *ERIC User Services: Evaluation in a Decentralized Environment*. Washington, D.C.: Dept. of Education.

Hsieh-Yee, Ingrid. (2000). *Organizing Audiovisual and Electronic Resources for Access: A Cataloging Guide*. Littleton, CO: Libraries Unlimited.

Hsieh-Yee, I. (2000). Organizing Internet Resources: Teaching Cataloging Standards and Beyond. *OCLC Systems & Services,* 16: 130-143. (Received "The Most Outstanding Paper of OCLC Systems & Services in 2000" award.)

Hsieh-Yee, I. (1998). The Retrieval Power of Selected Search Engines: How Well Do They Address General Reference Questions and Subject Questions? *Reference Librarian,* 60: 27-47.

Hsieh-Yee, I. (1998). Search Tactics of Web Users in Searching for Texts, Graphics, Known Items and Subjects: A Search Simulation Study. *Reference Librarian,* 60: 61-85. (Received the 1997 Best ALISE Research Paper Award.)

Hsieh-Yee, I. (1997). Access to OCLC and Internet Resources: LIS Educators' Views and Teaching Practices. *RQ,* 36: 569-86.

Hsieh-Yee, I. (1997). Teaching Online and CD-ROM Resources: LIS Educators' Views and Practices. *Journal of Education for Library and Information Science,* 38: 14-34.

Hsieh-Yee, I. (1996). The Cataloging Practices of Special Libraries and Their Relationship with OCLC. *Special Libraries,* 87: 10-20.

Hsieh-Yee, I. (1996). Modifying Cataloging Practice and OCLC Infrastructure for Effective Organization of Internet Resources. In *Proceedings of the OCLC Internet Cataloging Colloquium*. [Online]. Available: http://www.oclc.org/oclc/man/colloq/hsieh.htm

Hsieh-Yee, I. (1996). Student Use of Online Catalogs and Other Information Channels. *College & Research Libraries,* 57: 161-175.

Hsieh-Yee, I. (1995). Ten entries in James S. C. Hu (Ed.), *Encyclopedia of Library & Information Science*, 913, 1028-29, 1036, 1037, 1145-46, 1514, 1575, 1763-64, 2216-27, 2378-79. Taipei, Taiwan: Sino-American Publishing. (Topics include "Advanced Technology/Libraries," "Information Ethics," "Instruction on Cataloging and Classification," "Instruction on Reference Services.")

Hsieh-Yee, I. (1993). Effects of Search Experience and Subject Knowledge on Online Search Behavior: Measuring the Search Tactics of Novice and Experienced Searchers. *Journal of the American Society for Information Science,* 44: 161-174. (Received the 1993 Best JASIS Paper Award.)

Works in Progress

Hsieh-Yee, I. Actionable lessons for debunking false information: A comparative analysis of literacy lessons in communication and library and information science

Hsieh-Yee, I. Representing diverse voices and communities in cataloging and indexing: The evolution of controlled vocabularies

Hsieh-Yee, I. Information Organization and Retrieval in Practice (a monograph scheduled for completion and publication in 2023)

Presentations

Bailey, T. & Hsieh-Yee, I. (February 2020). The Phenomena of Sharing Misinformation and the Need for Information Literacy. Presented at the 2020 Bridging the Spectrum Symposium, Washington, D.C., February 14, 2020.

Hsieh-Yee, I. and Fragan-Fly, J. (May 2018) Trends, Design & Strategies for Digital Scholarship Services. Presented at the 2018 Maryland/Delaware Library Association Conference, Cambridge, MD.

Hsieh-Yee, I. (February, 2018) Research Data Management: What It Takes to Succeed. Presented at the 10th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. (February, 2017) *Research Data Management: New Competencies and Opportunities for Information Professionals*. Presented at the 9th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. and Lawton, P. (February, 2017) *Enhancing Catholic Portal Searches with User Terms and LCSH*. Presented at the 9th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. (2016, October) *Visualizing Data for Information*. Presented at the 2016 Virginia Library Association Conference, Hot Springs, VA.

Hsieh-Yee, I. (2016, August) *Religious Materials Toolbox for Archivists: Solutions to Problems Facing the Profession*. Presented at Archives * Records 2016, Atlanta, GA.

Hsieh-Yee, I. and Lawton, P. (2016, March) *Enhancing Retrieval of Catholic Materials with LCSH Knowledge Structure*. Presented at the 2016 Catholic Library Association Conference, San Diego, CA.

Fagan-Fry, J. and Hsieh-Yee, I. (2016, February) *Approaches to Digital Scholarship at Top Universities around the World: Scholarly Publishing in the Digital Age.* Presented at the 8th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee and Fagan-Fry, J. (2016, January) *Innovative Services for Digital Scholarship at Top 100 Research Libraries of the World*. Poster presented at the 2016 Annual Conference of the Association for Library and Information Science Education, Boston, Mass.

Hsieh-Yee, I. and Lawton, P. (2015, June). *Crowdsourcing terms for CRRA portal themes.* Poster presented at the third CRRA symposium and annual meeting, Bringing the created toward the Creator: Liturgical art and design since Vatican II. Catholic Theological Union, Chicago, Illinois.

Hsieh-Yee, I. and Lawton, P. (2015, February). *Crowdsourcing terms for thematic exploration in the Catholic Portal.* Poster presented at the 7th Annual Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I., James, R., and Fagan-Fry, J. (2015, February). *Support for digital scholarship at top university libraries of the world*. Poster presented at the 7th Annual Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I., Zhang, S., Lin, K., and Cherry, S. (2015, February). *Thus said the end users: Summon experience and support for research workflows*. Poster presented at the 7th Annual Bridging the Spectrum Symposium, Washington, D.C.

Yontz, E., Hsieh-Yee, I., & Houston, S. (2015, February). *Healthy Heroes Summer Reading Club: Developing healthy youth at public libraries.* 11th Annual Jean Mills Health Symposium, Greenville, North Carolina.

Yontz, E., Hsieh-Yee, I., and Houston, S. (2015, January). *Healthy youth and libraries: A pilot study.* Association for Library & Information Science Education (ALISE) Annual Conference, Chicago, Illinois.

Hsieh-Yee, I. (2014, May). *Linking CRRA resources to portal themes via authority files*. Presented at the Catholic Research Resources Alliance 2014 Membership Meeting, Marquette, WI.

Hsieh-Yee, I. (2014, April). *Enhancing subject access to CRRA resources*. Presented at the 2014 Catholic Library Association Conference, Pittsburgh, PA.

Hsieh-Yee, I. (2014, January). *Health Information Technology Program: Educational entrepreneurship in action*. Presented at the 2014 annual Conference of the Association for Library and Information Science Education, Philadelphia, PA

Hsieh-Yee, I., Zhang, S., Lin, K., and Cherry, S. (2014, January). *Discovering information through Summon: An analysis of user search strategies and search success*. Paper presented at the 6th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. (2012, December). *National Digital Stewardship Alliance and SLIS at CUA: An Educational Partnership*. Paper presented at Best Practices Exchange: Acquiring, Preserving, and Providing Access to Government Information in the Digital Era, Annapolis, MD

Choi, Y. and Hsieh-Yee, I. (2010, January). *Finding Images in an OPAC: Analysis of User Queries, Subject Headings, and Description Notes*. Paper presented at 2nd Annual Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. and Coogan, J. (2010, January). *Google Scholar vs. Academic Search Premier: What Libraries and Searchers Need to Know*. Paper presented at 2nd Annual Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (2009, November). *Information Science Education: An LIS School's Perspective*. Paper presented at Annual Meeting of the American Society for Information Science and Technology, Vancouver, British Columbia, Canada.

Hsieh-Yee, I., Menard, E., Ya-Ning Chen, A., Shu-Jiun Chen, S., Kalfatovic, M. R., Wisser. K. M. (2009, November). *Information Organization in Libraries, Archives and Museums: Converging Practices and Collaboration Opportunities*. Presented at Annual Meeting of the American Society for Information Science and Technology, Vancouver, British Columbia, Canada. (Organizer and moderator of this panel.)

Hsieh-Yee, I. and Coogan, J. (2009, July). *Catching up to Google Scholar: The Retrieval Power of Academic Search Premier and Google Scholar*. Poster presented at American Library Association Conference, Chicago, Illinois.

Hsieh-Yee, I., with the CUA Scholarly Communications Project Team. (2009, January). *Digital Scholarship@CUA: Developing an Institutional Repository for CUA*. Poster presented at 1st Annual Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Wise, M., Cylke, K., and Hsieh-Yee, I. (2009, January). *Digital Talking Books: Meeting the Needs of the Blind and the Handicapped*. Paper presented at the Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (2009, January). *User Expectations of MERIC*. Presented at the Information Organization Competencies for the 21st Century Discussion Session of the 2009 Conference of the Association for Library and Information Science Education, Denver, Colorado.

Choi, Y., and Hsieh-Yee, I. (2008,November). *Subject Access for Images in an OPAC.* Annual Meeting of the American Society for Information Science and Technology, Columbus, Ohio. (Also co-organized a panel on Retrieving and Using Visual Resources: Challenges and Opportunities for Research and Education.)

Hsieh-Yee, I. (2008, June). *Educating Cataloging Professionals in a Changing Information Environment*. National Taiwan University, Taipei, Taiwan.

Vellucci, S. L., Moen, W.E., Hsieh-Yee, I., Marson, B., and Wisser, K. (2008, January) *Building a Metadata Education and Research Community through MERIC (Metadata Education and Research Information Commons): Demo and Stakeholder Input*. A panel presented at the 2008 Conference of the Association for Library and Information Science Education, Philadelphia, Pennsylvania.

Hsieh-Yee, I., Choi,Y. and Kules, B. (2007, October). *Searching for Books and Images in OPAC: Effects of LCSH, TOC and Subject Domains.* A poster presented at the American Society for Information Science and Technology Annual Meeting, Milwaukee, Wisconsin.

Hsieh-Yee, I. and Coogan, J. (2007, August) *Google Scholar vs. Academic Search Premier: A Comparative Analysis.* Presented to the Faculty and Staff of the University of the District

of Columbia.

Hsieh-Yee, I. and Coogan, J. (2007, June). *Google Scholar vs. Academic Search Premier: A Comparative Analysis*. Presented to the Washington Research Library Consortium Community, Catholic University of America, Washington, D.C.

Hsieh-Yee, I., Choi, Y., and Kules, B.. (2007, June). *What Users Need for Subject Access: Table of Contents or Subject Headings?* A poster presented at the 2007 American Library Association Annual Conference, Washington, D.C., June 2007.

Choi, Y., Hsieh-Yee, I., and Kules, B. (2007, June). *Retrieval Effectiveness of TOC and LCSH.* A paper presented at the Joint Conference on Digital Libraries 2007, Vancouver, Canada.

Vellucci, S. L., Hsieh-Yee, I., and Moen, W.E. (2007, May). *If We Build It, Will They Come? Building a Community of Practice for Metadata Stakeholders.* A poster presented at the Rutgers University Research Day, Bridgeton, New Jersey.

Hsieh-Yee, I. (2007, May). *Federated Searching: User Experience & Perceptions.* International Conference on Information Organization & Retrieval, National Taiwan University, Taipei, Taiwan.

Hsieh-Yee, I. (2007, May). *Search Performance of Google Scholar and Academic Search Premier.* International Conference on Information Organization & Retrieval, National Taiwan University, Taipei, Taiwan.

Hsieh-Yee, I. (2007, May) *MERIC: Building a Digital Commons for Metadata Education & Research.* International Conference on Information Organization & Retrieval, National Taiwan University, Taipei, Taiwan.

Hsieh-Yee, I., and Coogan, J. (2007, March/April). *A Comparative Analysis of Google Scholar and Academic Search Premier.* Poster presented at the Association of College & Research Libraries 13th National Conference, Baltimore, Maryland.

Vellucci, S. L. and Hsieh-Yee, I. (2007, March/April) *They Didn't Teach Me That in Library School! Building a Digital Teaching Commons to Enhance Metadata Teaching, Learning and Research*. On-site presentation and Webcast by Elluminate. A contributed paper presented at the Association of College & Research Libraries 13th National Conference, Baltimore, Maryland. The acceptance rate for contributed paper was 20%. This paper was one of 10 conference papers chosen for live webcast during the conference.

Moen, W., Hsieh-Yee, I. and Vellucci, S.L. (2007, January) *A DSpace Foundation for a Teaching & Research Commons: The Metadata Education and Research Information Commons.* A poster session presented at the Open Repositories Conference 2007, San Antonio, Texas.

Tang, R., Hsieh-Yee, I., and Zhang, S. (2006, November) *User Perception of MetaLib Combined Search*. Paper presented at the Annual Meeting of the American Society for Information Science and Technology, Austin, Texas, Nov. 2006.

Hsieh-Yee, I. (2006, November). *Federated Searching: User Perceptions, System Design, and Library Instructions.* Paper presented at the Annual Meeting of the American Society for Information Science and Technology, Austin, Texas. (Panel organizer, moderator, presenter).

Hsieh-Yee, I. (2006, November). *Building a Digital Teaching Commons to Enhance Teaching and Learning: The MERIC Experience and Challenges.* Paper presented at the Annual Meeting of the American Society for Information Science and Technology, Austin, Texas. (Panel organizer, moderator, presenter)

Hsieh-Yee, I. (2006, September). *Search Performance of Google Scholar and Academic Search Premier.* Paper presented at the ERIC Publishers Meeting, Washington, D.C.

Hsieh-Yee, I., Zhang, S., and Rong Tang, R. (2006, June). *User Perceptions of a Federated Search System*. Poster presented at Joint Conference on Digital Libraries, Chapel Hill, North Carolina.

Hsieh-Yee, I. and Zhang, S. (2006, June). *Preparing Users for Federated Search: Implications of a MetaLib User Perceptions Study.* Paper presented at the 2006 Ex Libris User Groups of North America Conference, Knoxville, Tennessee.

Hsieh-Yee, I. (2006, January). *MERIC Organizations and Navigation*. Paper presented at the 2006 ALISE Annual Conference, San Antonio, Texas.

Hsieh-Yee, I. (2006, January). *Metadata and Cataloging Education: Recommended Competencies.* Paper presented at the 2006 ALISE Annual Conference, San Antonio, Texas.

Hsieh-Yee, I. (2005, November). *Digital Library Evaluation: Progress & Next Steps.* Presentation at the Annual Meeting of the American Society for Information Science & Technology, Charlotte, North Carolina.

Hsieh-Yee, I. (2005, August). *Providing Access to Digital Content: Issues for DL Managers.* Presentation at MDK12 Digital Library Steering Committee Meeting, Columbia, Maryland.

Hsieh-Yee, I. (2005, April). *Enhancing Teaching and Learning: The Role of School Library Media Specialists.* Presentation at Meeting of the Baltimore County Public School System School Media Specialists, Baltimore, Maryland.

Hsieh-Yee, I. (2005, January). *Subject Access and Users: Insights & Inspirations from Marcia J. Bates.* Paper presented at the Historical Perspectives SIG, 2005 Conference of the Association for Library and Information Science Education, Boston, Massachusetts.

Hsieh-Yee, I. (2005, January). *Electronic Resource Management: Practice, Employer Expectations, & CE Interests.* Paper presented at Technical Services Education SIG, 2005 Conference of the Association for Library and Information Science Education, Boston, Massachusetts.

Hsieh-Yee, I. (2004, October). *Library Professionals for the Digital Age: Competencies & Preparation.* Paper presented at Bibliographic Access Management Team meeting, Library of Congress, Washington, D.C.

Hsieh-Yee, I. (2004, January). *Cataloging and metadata expertise for the digital era.* Presented at Preparing 21st Century Cataloging and Metadata Professionals: A Workshop for Educators and Trainers, San Diego and sponsored by ALCTS, ALISE, LC, and OCLC.

Hsieh-Yee, I. (2004, January). *Educating catalogers for the digital era.* Paper presented at the Technical Services SIG, 2004 Conference of the Association for Library and Information Science Education, San Diego.

Hsieh-Yee, I. (2003, July). *Cataloging Education for the 21st Century.* A presentation at the Library of Congress, Washington, D.C.

Hsieh-Yee, I. (2002, January) *Metadata Education and Research Priorities: A Delphi Study of Metadata Experts.* Presentation at the 2002 Conference of the Association for Library and Information Science Education, New Orleans.

Hsieh-Yee, I. (2001, November). *A Delphi Study of Metadata: Preliminary Findings.* Poster session at the 2001 Annual Meeting of the American Society for Information Science & Technology, Washington, D.C.

Hsieh-Yee, I. (2001, June). *Resources on Asian American Children: Analysis of Retrieval by Search Engines and WorldCat.* Presentation at the National Conference on Asian Pacific American Librarians, San Francisco.

Hsieh-Yee, I. (2001, January). *Delphi Study on Metadata: Project Design.* Presentation at Research Awards Session, Association for Library & Information Science Education, Washington, D.C.

Hsieh-Yee, I. (2000, May). *Web Search Behavior Research: Progress and Implications.* Presentation at the Symposium on Evaluating Library and Information Science Research, University of Wisconsin-Madison, Madison, Wisconsin.

Hsieh-Yee, I. (2000, March). *ERIC User Services: Evaluation in a Decentralized Environment.* Presentation at the National ERIC Joint Directors/Technical Meeting, Arlington, Virginia.

Hsieh-Yee, I. (2000, January). *Enhancing Learning with Web Technology.* Presentation at Faculty Conversations, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (2000, January). *From Surrogates to Objects: CUA's Approaches to Organizing Electronic Resources.* Paper presentation at the Annual Conference of the Association for Library and Information Science Education, San Antonio, Texas.

Yee, P., and Hsieh-Yee, I. (1997, November). *Individual Differences in Search Behavior on the WWW.* A poster session presented at the 38th Annual Meeting of the Psychonomic Society, Philadelphia, Pennsylvania.

Hsieh-Yee, I. (1997, April). *Research + Marketing + Preparation = Job!* Presented at the "Workshop on Resume and Interview Techniques," Special Libraries Association, Student Chapter, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (1997, February). *Creating CyberCatalogers: Education and Training.* Presentation at ALA's Midwinter Meeting, Washington, D.C.

Hsieh-Yee, I. (1997, February). *Search Tactics of Web Users in Searching for Texts, Graphics, Known Items and Subjects: A Search Simulation Study.* Presented at the Conference of the Association for Library and Information Science Education, Washington, D.C.

Hsieh-Yee, Ingrid. "Beginning Your Special Library/Information Center Career." Presented at SLA's "Career Day," Jan. 11, 1997, Catholic University of America.

Hsieh-Yee, I. (1996, September). *The Roles of Library and Information Scientists in Managing Electronic Information.* Presentation at Hamilton College, Clinton, New York.

Hsieh-Yee, I. (1996, May). *The Future of Cataloging as a Profession.* Presented at "The Cataloging Forum, Library of Congress, Washington, D.C.

Hsieh-Yee, I. (1994, October). *The Impact of the Internet on OPACs.* Presented at the Third Workshop on User Interfaces for OPACs, Library of Congress, Washington, D.C.

Reports

Hsieh-Yee, I., with Knowledge Management Competencies and Performance Action Group of the Federal Knowledge Management Initiative. "From Knowledge Management Competencies to Improved Organizational Performance." April 9, 2009.

Hsieh-Yee, I., with Knowledge Practices Action Group of the Federal Knowledge Management Initiative. "KM Practice in Government Agencies: Findings and Recommendations." April 9, 2009.

Hsieh-Yee, I. "Delphi Study on Metadata." 2001. Three quarterly reports submitted to the Association for Library and Information Science Education.

Hsieh-Yee, I. "College Students' Information Channels: Patterns of Use and Possible Factors in Channel Selection." 1995. Submitted to the Catholic University of America.

Hsieh-Yee, I. "The Information-Seeking Patterns of Scholars and Their Use of an Online Information System." 1994. Submitted to the Council on Library Resources.

Book Reviews

Review of *The Measurement and Evaluation of Library Services*, by Sharon L. Baker and F. Wilfrid Lancaster. *Information Processing and Management* 30 (1994): 450-52.

Review of *Subject Access to Films and Videos, by Sheila S. Intner and William E. Studwell; and Cataloging Unpublished Nonprint Materials*, by Verna Urbanski with Bao Chu Chang and Bernard L. Karon. *Information Processing and Management* 30 (1994): 449-50.

Review of *Automated Information Retrieval in Libraries: A Management Handbook*, by Vicki Anders. *Journal of Library and Information Science* 19 (1993): 98-100.

Review of *Full Text Databases*, by Carol Tenopir and Jung Soon Ro. *Information Processing and Management* 28 (1992): 667-68.

Review of *Descriptive Cataloging for the AACR2R And USMARC: A How-to-Do It Workbook*, by Larry Millsap and Terry Ellen Ferl. *Information Processing and Management* 28 (1992): 809-11.

Review of *MARC Manual: Understanding and Using MARC Records*, by Deborah J. Byrne. *Information Processing and Management* 28 (1992): 537-38.

Service

Professional Associations and Societies

- Library of Congress. RDA Training Program for the Profession. Co-authored with Tim Carlton. 2013-2014.
- 2014 Digital Preservation Outreach & Education Survey. Contributed to the design of the survey, 2014.
- National Digital Stewardship Alliance. Outreach Committee. 2011-2014.
- National Digital Stewardship Residency Program. Advisory Group, 2012-2013.
- FEDLINK Health Information Technology Advisory Council, 2011-2015.

- 2012 Joint Conference on Digital Libraries. Program Planning Committee, Pre-Conference Proposals Review Committee, 2012
- Catholic Research Resources Alliance. Five-Year Strategic Plan Task Force, 2011-2012
- Institute of Museum and Library Services. Grant reviewer. 2004, 2005, 2010.

- Association for Library and Information Science Education.
  * ALISE Bodan Wynar Research Paper Award Committee, 2015, 2016, 2017
  * ALISE Eugene Garfield Dissertation Award Competition, Jury, 2013, 2014
  * ALISE Research Grant Competition Committee. Chair, 2012
  * Pratt-Severn Faculty Innovation Award. Chair, 2009, 2010
  * ALISE Doctoral Poster Jury, 2012
  * "Information Organization Competencies for the 21st Century" Discussion session leader. 2009 Conference of the Association for Library and Information Science Education.
  * Assisted Technical Services SIG Convener in organizing a program, ""Building a Metadata Education and Research Community through MERIC (Metadata Education and Research Information Commons): Demo and Stakeholder Input" for the 2008 ALISE conference.
  * Association for Library Collections and Technical Services/Association for Library and Information Science Education (ALCTS/ALISE) Metadata Education and Research Information Center (MERIC) Advisory Board, Co-Chair (with Sherry Vellucci), 2005-2007. Chair, 2008-2009 (leading the effort to build MERIC, a repository and collaborative space for metadata educators, practitioners, and researchers)
  * Technical Services SIG, Convener, 2004-2005. Organized a program on "Electronic Resources Management: Current Practices, Employer Expectations, and Teaching Strategies" for the 2005 conference in Boston, Massachusetts.
  * Technical Services SIG, Convener, 2003-2004. Organized a program on "Organizing Information with Metadata: Desired Competencies and Teaching Innovations" for the 2004 conference.
  * Technical Services SIG, Convener, 1999-2000. Organized a program on "Teaching the Organization of Electronic Resources" for the 2000 conference.
  * Curriculum SIG, Co-convener (with Sibyl Moses), 1996-97. Organized a program on "Government Information Policy" for the 1997 conference.

- American Society for Information Science & Technology.
  * Reviewer, Conference program panel submissions and poster submissions, 2005, 2006, 2007, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017
  * Nomination Committee, 2009-2011
  * Information Science Education Special Interest Group. American Society for Information Science and Technology. Chair-Elect, 2007-2008. Chair 2008-2009.
  * Committee on Information Science Education. 1999-2006.
  * Committee on Information Science Education. Organizing Committee for an orientation program for students at ASIS annual meetings, 1999-2001
  * Committee on Information Science Education. Sub-committee on Student Welfare (focusing on issues related to master's education), 1998-2001

* SIG ED. Organizing Committee for the "Seminar on Research and Career Development" for junior researchers. 1995-96 (chair), 1997-2001
* ISI Doctoral Dissertation Proposal Scholarship Jury, 1997; 2001, 2002
* Pratt-Severn Best Student Research Paper Award Jury. Chair. 1997
* 1998 Midyear Meeting (referee of contributed papers), 1997
* Organizer and moderator of the ASIS Doctoral Forum and the Doctoral Research Seminar 1994-1995
* SIG Human Computer Interaction. Chair-Elect, Chair, 1993-1995
* Doctoral Forum Award Jury, 1995
* Best Student Paper Award Jury, 1995

- American Library Association.
  * Committee on Accreditation, External Review Panelist, 2009- (site visiting team 2013-2014; site visiting team 2016-2017)
  * Association for Library Collections and Technical Services Task Force on Competencies and Education for a Career in Cataloging, member, 2008-2009
  * Facilitator for "What They Don't Teach in Library School: Competencies, Education and Employer Expectations for a Career in Cataloging," an Association for Library Collections and Technical Services Preconference, June 22, 2007 in Washington, D.C. Also a local liaison for bringing this program to the Catholic University of America.
  * Facilitator for a discussion on "Effect of Electronic Resources on Technical Services" at ALA's Midwinter Meeting held in Feb. 1997 in Washington, D.C.
  * International Relations Committee, Subcommittee Task Force for IFLA and China, 1994-1997

- Virginia Association of School Librarians. Scholarships and Awards Committee. 2010-2012

- Federal Knowledge Management Initiative, Knowledge Management Practices Action Group. Member. 2009 (leading the effort to build a knowledge management repository)
- Federal Knowledge Management Initiative, Knowledge Management Competencies & Learning Action Group. Member. 2009 (developing an action plan for helping government knowledge workers and government agencies to develop knowledge management competencies)
- National Center for Education Statistics. Technical Review Panel. 2008.
- External evaluator for a case of promotion to full professorship. University of Tennessee. 2008.
- National Information Standards Organization (NISO). Advisory Board, Revision of "IMLS Framework of Guidance for Building Good Digital Collections," 2004, 2007.
- Library of Congress, Bibliographic Control of Web Resources: A Library of Congress Action Plan. Principal Investigator of Action Item 5.1, focusing on cataloging and metadata education for students and new librarians, 2002-2003. (worked with the Association for Library Collections and Technical Services, Education Task Force)

- Chinese American Librarians Association
  * Chinese American Librarians Association Outstanding Library Leadership Award in Memory of Dr. Margaret Chang Fung, Award Committee, 2016-2017
  * Achievement Award Jury, 2000-2001
  * CALA Goal 2000 Task Force, 1997
  * Scholarship Committee, 1995, 1996-1997 (chair)
  * Board of Directors, 1994-1997
  * Publication Committee, 1993-1995
  * International Relations Committee, 1993-1996

- Sailor[SM] Assessment Advisory Group (An impact study of Sailor, Maryland's Public Information Network), 1995

- Editorial boards
  Journal of Library & Information Science. Editorial Board, 2012-
  Chinese American Librarians Association, *Occasional Papers Series*. Editorial Board, 2009-2016.
  Library Quarterly. Editorial Board, 2003-2008
  Bulletin of the Medical Library Association, 1994-97
  Newsletter editor for the Chinese American Librarians Association, 1989-92

- Referee for the following journals
  Information Processing and Management
  Journal of Digital Information
  Journal of Education for Library and Information Science
  Journal of Information Science
  Journal of Library & Information Science
  Journal of Library Metadata
  Journal of the American Society for Information Science & Technology
  Library and Information Science Research
  Library Quarterly

- Expert reviewer, "Digital Library" course, Evaluation module, University of North Carolina, Chapel Hill, 2007-2008.
- Expert reviewer, "Information Organization" course, University of Michigan, Ann Arbor. 2007.

Catholic University of America

- Academic Senate Committee on Appointments and Promotions, 2005-2008
- Academic Senate Committee on Committees and Rules, 2009-2012, 2019-2022
- Academic Senate representative (for School of Arts & Sciences), 2017-2020

- Academic Senate representative (for School of Library & Information Science) 2003-2012
- Academic Senate Library Committee, Interim Chair (2007), Member, 2008-2012
- Academic Senate Committee on Computing, 1995-2003

- President's Administrative Council, 2010-2012
- Deans' Council, 2010-2012
- Academic Leadership Group, 2010-2012
- Graduate Board, 2010-2012

- School of Arts & Sciences, Committee on Appointments and Promotions, 2015-2019
- School of Arts & Sciences, Academic Council, 2015-2016.
- School of Arts & Sciences, Ordinary Professor Group, 2013-
- Doctoral Dissertation Defense Committee, Chair, Dept. of Psychology, 2016, 2017, 2018, 2019, 2020, 2021, 2022
- Doctoral Dissertation Defense Committee, Chair, Dept. of Education, 2014, 2015, 2017, 2018, 2019
- Doctoral Dissertation Defense Committee, Chair, National Catholic School of Social Services, 2019, 2020, 2021
- Doctoral Dissertation Defense Committee, Chair, School of Nursing, 2006, 2008
- CUA Scholarly Communication Project Team, Member (2007), Chair, 2008-2009
- Dean Search Committee, 1992-1994, 1998-1999, 2002-2003, 2006-2007
- Fulbright Review Panel, 2006
- CUA Service Learning Advisory Board, 2001-2002
- CUA Faculty Conversations on Enhancing Teaching and Learning through Technology, Planning Group, 1999-2001
- CUA Initiative on Technology and Teaching, 1998-2001

Dept. of Library and Information Science

- Admissions Committee, 2007-2009, Chair 2010-2012, Member 2013-2015, Member 2018-2022
- Appointments and Promotions Committee, 1991-2022
- Student advisement, 1990-2022
- 4+1 Bachelor to Master program, Program Advisor, 2014-2022
- LIS Minor, Advisor, 2017-2022
- Curriculum Committee, 2020-21 (Member), 2021-2022 (Chair)
- Scholarship & Awards Committee, 2016-2018, 2020-21
- Comprehensive examination editor, 2020-21
- Symposium, Colloquium, Lecture Series Committee, May 2018-May 2020 (Chair)
- Symposium and Colloquium Committee, fall 2016-May 2018
- Bridging the Spectrum Symposium session moderator, 2018, 2019, 2020, 2021

- Organization of Information Core Course Outcomes Assessment, 2019, 2020
- The Information Professions in Society Core Course Outcomes Assessment, 2019, 2020
- Community Services Librarianship, Course of Study Review and Revision, 2020
- Organization of Information, Course of Study Review and Revision, 2019
- Organization of Information, Competency and Course Offerings Review, 2018-2019
- Accreditation presentation, Chair, June 2015-August 2016
- Interim Co-Chair, June 2015-August 2016.
- Blended/OWL Learning Committee, spring 2016-2018
- Technology Committee, fall 2016-2017
- Comprehensive examination editor, 2016-2017, reader (every year since 1990)
- LIS Advisory Board, 2015-2016 (chair); fall 2016- May 2018 (member)
- Committee on Planning and Assessment, 2015-2016 (chair)
- Senior Faculty Committee, 2014-2016.
- Accreditation Steering Committee, 2014-2016 (Chair, 2015-2016)
- Accreditation Students Standard Committee, co-chair, 2014-2016
- Accreditation Mission, Goals, and Objectives Standard Committee, co-chair, 2014-2016
- Accreditation Curriculum Standard, member 2014-2-16
- Accreditation Administration and Finance Standard, member 2014-2016
- Cultural Heritage Information Management Project (IMLS-funded), Co-PI, 2012-2015
- Cultural Heritage Information Management Forum (scheduled for June 2015), Co-Organizer, 2013-2015
- Health Information Technology Interim Review Committee, 2015 (chair)
- Health Sciences Librarianship Advisory Group, 2015- (chair)
- Comprehensive examination editors, 2013-2014, 2016-2017
- National Digital Stewardship Alliance liaison, 2011-2014
- Advisory Board, Chair 2010-2012
- Academic Honesty Committee, Chair, 2008-2012
- Blended Learning Committee, 2010-2012
- Colloquium Committee, 2010-2012
- Comprehensive Examination Administration, 2010-2012
- Cultural Heritage Information Management Advisory Committee, 2010-2012 (chair), 2013-
- Curriculum Committee, 1991-2003, 2007-2009, Chair 2010-2012, member 2013-
- Curriculum Subcommittee on Comprehensive Examination, Chair 2009-2012
- Health Information Technology Advisory Board, Chair 2010-2012. Member 2013-
- Health Sciences Advisory Committee, 2009, Chair 2010-2012. Member 2013-
- HIT Expert Forum, Chair 2012. Member 2013-2015
- Health Information Technology Student Group Advisor, 2011-2012
- State Council for Higher Education of Virginia, SLIS Representative, 2010-2012
- Symposium Planning Committee, 2010-2012
- Website Management Team, Chair, 2010-2012
- Urban School Librarianship Project (IMLS-Funded), PI, 2007-2011 (chair, 2010-11)

- Failing Grades Committee, 1995-1997 (chair), 2000-2001 (chair), 2004-2005 (chair), 2007 (chair)-2011
- Faculty Search Committee, 1994-1998, 2002-2004, 2006 (chair), Fall 2007-2009, Chair fall 2009-2012
- Recruitment Committee, Chair 2010-2012
- Strategic Planning Committee, Chair 2010-2012
- Technology Committee, 2010-2012
- Accreditation Advisory Committee, 2007-2009
- Accreditation Coordinating Committee, 2007-2009
- Accreditation Steering Committee, 2007-2009
- SLIS Advisory Group, 2007-2009
- Accreditation Curriculum Standard Committee, Co-chair, 2007-2009
- Accreditation Faculty Standard Committee, Co-chair, 2007-2009
- LSC 551 Information Organization Review Team, Co-chair, 2008-2009, 2015-2016.
- Curriculum Subcommittee on Portfolios, 2009
- LSC 555 Information Systems in Libraries and Information Centers Review Team, contributor, 2008-2009
- Redesign of LSC 730 Use and Users of Libraries and Information. 2009-
- Development of a metadata institute that was taught as LSC 715 Organization of Internet Resources in 2008. The institute is being revised and will be offered in 2010 under a new course title.
- Development of lesson plans, assignments, and evaluation rubrics for LSC 606, Cataloging and Classification, for the School's NCATE accreditation. 2008
- Howard and Mathilde Rovelstad Scholarship Committee, Chair, 2004-2007
- Assistant Dean Search Committee, Chair, Fall 2007
- Liaison to the Association for Library Collections and Technical Services to bring its preconference program, Cataloging Education and Employer Expectations, to CUA during the 2007 American Library Association Annual Meeting in Washington, D.C.
- Organizer of the colloquium presentation and reception for Tamar Sadeh of Ex Libris on PRIMO June 2007
- Practicum review and design (work with potential supervisors, such as the American Indian Museum internship description revision) 2006-
- Comprehensive examinations (edits, proctoring, and grading), 1990-
- SLIS Web site redesign: Comments and suggestions. Fall 2007
- Conducted surveys of current students and alumni in preparation for the 2005 re-accreditation, 2004-2005
- Technology Committee, 1992-1999 (chair, 1996-1998), 2002-2003 (member)
- Colloquia Committee 1997-1999, 2002-2003.
- Advisor of the CUA Student Chapter of the American Society for Information Science and Technology, 2002-2003
- Visiting Professor Search Committee, 1999, 2000, 2001
- Leader, Participation in the CORC experiment, 1999-2000
- Advisor of the Special Libraries Association Student Chapter, 1993-1999; the group was recognized for outstanding leadership by SLA in 1999.

- COA planning Committee, Task Force on Electronic Presentation of SLIS Reports (team leader) 1997-1998
- COA Planning Committee, Subcommittee on Technology 1996-1998
- NLM practicum coordinator, 1997-1998
- Computer Literacy Workshops: Assisted with the development and evaluation of the workshops, 1996-1998
- Leader, Participation in the InterCat project, 1995-1997

APPENDIX B

MARC 21 Reference Materials

Part VII: A Summary of Commonly Used MARC 21 Fields
Part VIII: A List of Other Fields Often Seen in MARC Records
Part IX: The Leader
Part X: Field 008 for Books

Part VII:

A Summary of Commonly Used MARC 21 Fields

This is a summary of the MARC 21 tags used most frequently by libraries in entering their own bibliographic records. For full listings of all MARC 21 tags, indicators, and subfield codes, see *MARC 21 Format for Bibliographic Data*.

In the explanations on these pages:

Tags -- The tags (3-digit numbers) are followed by the names of the fields they represent. In this summary, and in the *MARC 21 Format for Bibliographic Data*, if a tag can appear more than once in one bibliographic record, it is labeled repeatable (R). If it can only be used once, it is labeled non-repeatable (NR). For example, a catalog record can have several subjects, so the tags for subject added entries (6XX) are labeled repeatable (R).

Indicators -- The use of indicators is explained in fields where they are used. Indicators are one-digit numbers. Beginning with the 010 field, in every field -- following the tag -- are two character positions, one for Indicator 1 and one for Indicator 2. The indicators are not actually defined in all fields, however. And it is possible that a 2nd indicator will be used, while the 1st indicator remains undefined (or vice versa). When an indicator is undefined, the character position will be represented by the character # (for blank space).

Subfield codes -- All the data in each field (beginning with the 010 field) is divided into subfields, each of which is preceded by a delimiter-subfield code combination. The most common subfield codes used with each tag are shown. Each subfield code is preceded by the character $, signifying a delimiter. The name of the subfield follows the code.

In general, every field MUST have a subfield 'a' (**$a**). One exception that is often seen is in Field 020 (ISBN), when the ISBN information (subfield **$a**) is unavailable but the price (subfield **$c**) is known. Some subfields are repeatable. In this summary, repeatability is noted for only the more common repeatable subfields.

Examples: Examples follow the explanation for each field. For clarity, one space has been placed between the tag and the first indicator, one space has been placed between the second indicator and the first delimiter- subfield code, and one space has been inserted between the delimiter-subfield code and the subfield data.

010 Library of Congress Control Number -- (LCCN)
(NR, or Not Repeatable

Indicators undefined.
Subfield used most often:
$a -- Library of Congress control number

```
Example:    010 ##  $a ###86000988#
```

020 International Standard Book Number -- (ISBN)
(R, or Repeatable)

Indicators undefined.
Subfields used most often:
$a -- International Standard Book Number
$c -- Terms of availability (often a price)
$z -- Cancelled/invalid ISBN (R)

```
Example:    020 ##  $a 0877547637
```

040 Cataloging source -- (NR)

Indicators undefined.
Subfields used most often:
$a -- Original cataloging agency
$c -- Transcribing agency
$d -- Modifying agency (R)

```
Example:    040 ## $a DLC
                   $c DLC
                   $d gwhs
```

100 Main entry -- Personal name -- (primary author)
(NR; there can be only one main entry)

Indicator 1: Type of personal name entry element
0 -- Forename
1 -- Surname (this is the most common form)
3 -- Family name
Indicator 2 undefined.
Indicator 2 became obsolete in 1990. Older records may display 0 or 1
Subfields used most often:
$a -- Personal name
$b -- Numeration

$c -- Titles and other words associated with a name (R)
$q -- Fuller form of name
$d -- Dates associated with a name (generally, year of birth)

```
Example:    100 1# $a Gregory, Ruth W.
                   $q (Ruth Wilhelme),
                   $d 1910-
```

130 Main entry -- Uniform title -- (NR)

Indicator 1: Nonfiling characters
0-9 -- Number of nonfiling characters present (for initial articles, including spaces)
Indicator 2 undefined.
Indicator 2 became obsolete in 1990. (See 100 above.)
Subfields used most often:
$a -- Uniform title
$p -- Name of part/section of a work (R)
$l -- Language of a work
$s -- Version
$f -- Date of a work

```
Example:    130 0# $a Bible.
                   $p O.T.
                   $p Psalms.
```

240 Uniform title (NR)

Indicator 1: Uniform title printed or displayed
0 -- Not printed or displayed
1 -- Printed or displayed (most common)
Indicator 2: Nonfiling characters
0-9 -- Number of nonfiling characters present (for initial articles, including spaces)
Subfields used most often:
$a -- Uniform title
$l -- Language of a work
$f -- Date of a work

```
Example:    240 10 $a Ile mystérieuse.
                   $l English.
                   $f 1978
```

245 Title Statement (NR)

Indicator 1: Title added entry

(Should the title be indexed as a title added entry?)

0 -- No title added entry

(indicates a title main entry; i.e. no author is given)

1 -- Title added entry

(the proper indicator when an author given in 1XX; the most common situation)

Indicator 2: Nonfiling characters

0-9 -- Number of nonfiling characters present, including spaces; usually set at zero, except when the title begins with an article; e.g., for *The robe*, the second indicator would be set to 4. The letters *T*, *h*, *e*, and the space following them are then ignored in alphabetizing titles. The record will be automatically filed under "*r*" -- for *Robe*.

Subfields used most often:

$a -- Title proper

$h -- Medium (often used for non-book media)

$p -- Name of part/section of a work (R)

$b -- Reminder of title (subtitles, etc.)

$c -- Remainder of title page transcription/Statement of responsibility

```
Example:    245 14 $a The DNA story :
                   $b a documentary history of gene
                      cloning /
                   $c James D. Watson, John Tooze.
```

246 Varying form of title (R)

Indicator 1: Note/title added entry controller

1 -- Note, title added entry

3 -- No note, title added entry

Indicator 2: Type of title

-- No information provided

0 -- Portion of title

1 -- Parallel title

4 -- Cover title

8 -- Spine title

Subfield used most often:

$a -- Title proper

```
Example:    246 3# $a Four corners power review
```

250 Edition statement (NR)

Indicators undefined.
Subfield used most often:
$a -- Edition statement

```
Example:    250 ## $a 6th ed.
```

260 Publication, distribution, etc. (Imprint) (R)
Indicator 1: Sequence of publishing statements
-- No information provided
Indicator 2: Undefined
Subfields used most often:
$a -- Place of publication, distribution, etc. (R)
$b -- Name of publisher, distributor, etc. (R)
$c -- Date of publication, distribution, etc. (R)

```
Example:    260 ## $a New York :
                   $b Chelsea House,
                   $c 1986.
```

300 Physical description (R)
Indicators undefined.
Subfields used most often:
$a -- Extent (number of pages) (R)
$b -- Other physical details (usually illustration information)
$c -- Dimensions (cm.) (R)
$e -- Accompanying material (for example, "teacher's guide" or "manual")

```
Example:    300 ## $a 139 p. :
                   $b ill. ;
                   $c 24 cm.
```

440 Series statement / Added entry--Title
This field was made obsolete in 2008 to simplify the series statement. See 490 and 830.

490 Series statement (No added entry is traced from field) (R)
Indicator 1: Specifies whether series is traced (whether an 8XX tag is also present)
0 -- Series not traced
1 -- Series traced (8XX is in record)
Indicator 2 undefined.
Subfield used most often:

$a -- Series statement (R)
$v -- Volume number (R)

```
Example:    490 1# $a Colonial American craftsmen
```

500 General note (R)

Indicators undefined.
Subfield used most often:
$a -- General note (Used when no specialized note field has been defined for the information. Examples: Notes regarding the index; the source of the title; variations in title; descriptions of the nature, form, or scope of the item.)

```
Example:    500 ##  $a Includes index.
```

504 Bibliography, etc. note (R)

Indicators undefined.
Subfield used most often:
$a -- Bibliography, etc. note

```
Example:    504 ## $a Includes bibliographical
                      references.
```

505 Formatted contents note (R)

Indicator 1: Type of contents note
0 -- Complete contents
1 -- Incomplete contents (used with multivolume set when some volumes are not yet published)
2 -- Partial contents
Indicator 2: Level of content designation
-- Basic
Subfield used most often:
$a -- Formatted contents note

```
Example:    505 0# $a Pride and prejudice -- Emma
                      -- Northanger Abbey.
```

520 Summary, etc. note (R)

Indicator 1: Display constant controller
-- Summary

1 -- Review
2 -- Scope and content
3 -- Abstract

Indicator 2 undefined

Subfields used most often

$a -- Summary, abstract, or annotation
$b -- Expansion of summary note

```
Example:    520 ## $a This basic guide to parliamentary
                      procedure tells how to conduct
                      and participate in a meeting
                      properly.
```

600 Subject added entry -- Personal name (R)

Indicator 1: Type of personal name entry element

0 -- Forename
1 -- Surname (this is the most common form)
3 -- Family name

Indicator 2: Subject heading system/thesaurus (identifies the specific list or file which was used)

0 -- Library of Congress Subject Headings
1 -- LC subject headings for children's literature
2 -- Medical Subject Headings
3 -- National Agricultural Library subject authority file
4 -- Source not specified
5 -- Canadian Subject Headings
6 -- Répertoire de vedettes-matière
7 -- Source specified in subfield $2

(Note regarding Sears subject headings: The MARC 21 format does not provide an assigned indicator for Sears subject headings. Therefore, an indicator of 7 is used, and the MARC defined code "sears" is placed in subfield $2.)

Subfields used most often:

$a -- Personal name (surname and forename)
$b -- Numeration
$c -- Titles and other words associated with a name (R)
$q -- Fuller form of name
$d -- Dates associated with a name (generally, year of birth)
$t -- Title of a work
$v -- Form subdivision (R)
$x -- General subdivision (R)
$y -- Chronological subdivision (R)
$z -- Geographic subdivision (R)
$2 -- Source of heading or term (used with 2nd indicator of 7)

```
Example:    600 10 $a Shakespeare, William,
                   $d 1564-1616
                   $x Comedies
                   $x Stage history.
```

```
Example:    600 10 $a Shakespeare, William,
                   $d 1564-1616
                   $x Knowledge
                   $z Rome
                   $v Congresses.
```

Notice that subfields $v, $x, and $z in the 600 field are repeatable. Subfields $v, $x, $y, and $z do not have to be in alphabetical order. They will be in the order prescribed by the instructions given by the subject heading system.

610 Subject added entry -- Corporate name (R)

*Indicator 1:*Type of corporate name entry element

0 -- Inverted name (not used with AACR2)
1 -- Jurisdiction name
2 -- Name in direct order

Indicator 2: Subject heading system/thesaurus.

See indicator 2 under 600

Subfields used most often:

$a -- Corporate name or jurisdiction name as entry element
$b -- Subordinate unit (R)
$v -- Form subdivision (R)
$x -- General subdivision (R)
$y -- Chronological subdivision (R)
$z -- Geographic subdivision (R)
$2 -- Source of heading or term (used with 2nd indicator of 7)

```
Example:    610 10 $a United States.
                   $b Army Air Forces
                   $v Biography.
```

650 Subject added entry -- Topical term (Most subject headings fit here.) (R)

Indicator 1: Level of subject

-- No information provided

Indicator 2: Subject heading system/thesaurus
(identifies the specific list or file which was used)

0 -- Library of Congress Subject Headings
1 -- LC subject headings for children's literature

2 -- Medical Subject Headings
3 -- National Agricultural Library subject authority file
4 -- Source not specified
5 -- Canadian Subject Headings
6 -- Répertoire de vedettes-matière
7 -- Source specified in subfield $2

Note regarding Sears subject headings: The MARC 21 format does not provide an assigned indicator for Sears subject headings. Therefore, an indicator of 7 is used, and the MARC defined code "sears" is placed in subfield $2.)

Subfields used most often:

$a -- Topical term
$v -- Form subdivision (R)
$x -- General subdivision (R)
$y -- Chronological subdivision (R)
$z -- Geographic subdivision (R)
$2 -- Source of heading or term used with 2nd indicator of 7)

```
Example:    650 #0 $a Theater
                   $z United States
                   $v Biography
                   $v Dictionaries.
```

Notice that subfields $v, $x, and $z in the 650 field are repeatable. Subfields $v, $x, $y, and $z do not have to be in alphabetical order. They will be in the order prescribed by the instructions given by the subject heading system.

651 Subject added entry -- Geographic name (R)

Indicator 1: undefined.
Indicator 2: Subject heading system/thesaurus.
See indicator 2 under 600
Subfields used most often:

$a -- Geographic name
$v -- Form subdivision (R)
$x -- General subdivision (R)
$y -- Chronological subdivision (R)
$z -- Geographic subdivision (R)
$2 -- Source of heading or term (used with 2nd indicator of 7)

```
Example:    651 #0 $a United States
                   $x History
                   $v Chronology.
```

Notice that subfields $v, $x, and $z in the 651 field are repeatable. Subfields $v, $x, $y, and $z do not have to be in alphabetical order. They will be in the order prescribed by the instructions given by the subject heading system.

700 Added entry -- Personal name (R)

Indicator 1: Type of personal name entry element

0 -- Forename
1 -- Surname (this is the most common form)
3 -- Family name

Indicator 2: Type of added entry

-- No information provided (most common; co-authors, editors, etc.)
2 -- Analytical entry (The values for Indicator 2 changed in 1994 with Format Integration, and older records may display additional values. An analytical entry involves an author/title of an item contained in a work.)

Subfields used most often:

$a -- Personal name
$b -- Numeration
$c -- Titles and other words associated with a name (R)
$q -- Fuller form of name
$d -- Dates associated with a name (generally, year of birth)
$e -- Relator term (such as ill.) (R)
$4 -- Relator code (R)

```
Example:    700 1# $a Baldridge, Letitia.
```

710 Added entry -- Corporate name (R)

Indicator 1: Type of corporate name entry element

0 -- Inverted name (not used with AACR2)
1 -- Jurisdiction name
2 -- Name in direct order

Indicator 2: Type of added entry.

See Indicator 2 under 700
-- No information provided
2 -- Analytical entry

Subfields used most often:

$a -- Corporate name or jurisdiction name as entry element
$b -- Subordinate unit (R)

```
Example:    710 2# $a Sunburst Communications (Firm)
```

740 Added entry -- Uncontrolled related/analytical title (R)

Indicator 1: Nonfiling characters

0-9 -- Number of nonfiling characters present (for initial articles, including

spaces)

Indicator 2: Type of added entry. See Indicator 2 under 700

-- No information provided

2 -- Analytical entry

(This field was redefined in 1994 with Format Integration. Prior to 1994, the field was also used for variant titles, such as a different wording on a spine title. In records created since Format Integration, those variant tiles appear in a 246 field.)

Subfield used most often:

$a -- Title

```
Example:    740 02 $a Uncle Vanya.
```

800 Series added entry -- Personal name (R)

Indicator 1: Type of personal name entry element

0 -- Forename

1 -- Surname

3 -- Family name

Indicator 2 undefined.

Subfields used most often:

$a -- Personal name

$b -- Numeration

$c -- Titles and other words associated with a name (R)

$q -- Fuller form of name

$d -- Dates associated with a name (generally, year of birth)

$t -- Title of a work (the series)

$v -- Volume number

```
Example:    800 1# $a Fisher, Leonard Everett.
                   $t Colonial American craftsmen.
```

830 Series added entry -- Uniform title (R)

Indicator 1 undefined.

Indicator 2: Nonfiling characters

0-9 -- Number of nonfiling characters present (for initial articles, including spaces)

Subfield used most often:

$a -- Uniform title

$v -- Volume number

```
Example:    830 #0 $a Railroads of America (Macmillan)
```

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Part VIII:

A List of Other Fields Often Seen in MARC Records

001	Control number
003	Control number identifier
005	Date and time of latest transaction
006	Fixed-length data elements -- additional material characteristics
007	Physical description fixed field
008	Fixed length data elements (See Part X)
022	International Standard Serial Number (ISSN)
037	Source of acquisition
041	Language code
043	Geographic area code
050	Library of Congress call number
060	National Library of Medicine call number
082	Dewey Decimal classification number (the one recommended by the Library of Congress; locally-assigned call numbers may appear elsewhere)
110	Main entry -- Corporate name (less frequent under AACR2 rules)
256	Computer file characteristics
263	Projected publication date (indicates a CIP -- Cataloging in Publication -- record)
306	Playing time
508	Creation/production credits note
510	Citation/references note (review sources)
511	Participant or performer note
521	Target audience note (first indicator: 0 = reading grade level, 1 = interest age level, 2 = interest grade level, 3 = special audience characteristics, 4 = motivation interest level)
530	Additional physical form available note
538	System details note
586	Awards note
656	Index term -- Occupation
730	Added entry -- Uniform title
852	Location
856	Electronic location and access
9XX	Reserved for local use. (They are used by vendors, systems, or individual libraries to exchange additional data)

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Part IX:

The Leader

There are 24 positions in the Leader, numbered from 00 to 23. For fuller explanation, see the *MARC 21 Format for Bibliographic Data*.

00-04 Record length (calculated by the computer for each record)

05 Record status
- a = increase in encoding level
- c = corrected or revised
- d = deleted
- n = new
- p = increase in encoding from prepublication (previous CIP)

06 Type of record
- a = language material
- c = printed music
- d = manuscript music
- e = cartographic material
- f = manuscript cartographic material
- g = projected medium
- i = nonmusical sound recording
- j = musical sound recording
- k = 2-dimensional nonprojectable graphic
- m = computer file
- o = kit
- p = mixed materials
- r = 3-dimensional artifact or naturally occurring object
- t = manuscript language material

07 Bibliographic level
- a = monographic component part
- b = serial component part
- c = collection
- d = subunit
- i = integrating resource
- m = monograph/item
- s = serial

08 Type of control
- # = no specified type
- a = archival

09 Character coding scheme
- # = MARC-8
- a = UCS/Unicode

10 Indicator count (always "2")

11 Subfield code count (always "2")

12-16 Base address of data (calculated by the computer for each record)

17 Encoding level
- # = full level

1 = full level, material not examined
2 = less-than-full level, material not examined
3 = abbreviated level
4 = core level
5 = partial (preliminary) level
7 = minimal level
8 = prepublication level (CIP)
u = unknown
z = not applicable

18 Descriptive cataloging form
# = non-ISBD
a = AACR2
i = ISBD
u = unknown

19 Multipart resource record level
# = Not specified or not applicable
a = Set
b = Part with independent title
c = Part with dependent title

20 Length of the length-of-field portion (always "4")
21 Length of the starting-character-position portion (always "5")
22 Length of the implementation-defined portion (always "0")
23 Undefined (always "0")

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Part X:

Field 008 for Books

Field 008 is used for Fixed Length Data Elements ("Fixed Field Codes"). There are 40 character positions in field 008, numbered from 00-39. Undefined positions must contain either a blank (#) or a fill character (|). Positions 00-17 and 35-39 are defined the same way for all media.

The information shown here for positions 18-34 applies only to books. For explanation of all the positions below and for positions 18-34 for other media, see the *MARC 21 Format for Bibliographic Data*.

Note that field 008 has no indicators or subfield codes.

00-05 Date entered on file (YYMMDD),
where Y=year, M=month, and D=day

06 Type of date/publication status:
b = no dates given; B.C. date involved
e = detailed date
s = single known date/probable date
m = multiple dates
r = reprint/reissue date (Date 1) and original date (Date 2)

n = dates unknown
q = questionable date
t = publication date and copyright date
| = no attempt to code

07-10 Date 1/beginning date of publication
11-14 Date 2/ending date of publication

Date fields contain the year(s) of publication. The type of date(s) in these elements are specified in fixed field element 06: Type of date/publication status. (For further details, see the field 008 description in the *MARC 21 Format for Bibliographic Data*.)

15-17 Place of publication, production, or execution
For example:
pk# = Pakistan
cau = California (US)

(For a full list of codes used in these positions, see the *MARC Code List for Countries*.)

18-21 Illustrations (up to 4 codes):
# = no illustrations
a = illustrations
b = maps
c = portraits
d = charts
e = plans
f = plates
g = music
h = facsimiles
i = coats of arms
j = genealogical tables
k = forms
l = samples
m = phonodisc, phonowire, etc.
o = photographs
p = illuminations
| = no attempt to code

22 Target audience:
# = unknown or not specified
a = preschool
b = primary
c = pre-adolescent
d = adolescent
e = adult
f = specialized
g = general
j = juvenile
| = no attempt to code

23 Form of item:
# = none of the following
a = microfilm

b = microfiche
c = microopaque
d = large print
f = braille
r = regular print reproduction
s = electronic
| = no attempt to code

24-27 Nature of contents (up to 4):

# = no specified nature of contents
a = abstracts/summaries
b = bibliographies (is one or contains one)
c = catalogs
d = dictionaries
e = encyclopedias
f = handbooks
g = legal articles
i = indexes
j = patent document
k = discographies
l = legislation
m = theses
n = surveys of literature
o = reviews
p = programmed texts
q = filmographies
r = directories
s = statistics
t = technical reports
u = standards/specifications
v = legal cases and notes
w = law reports and digests
z = treaties
| = no attempt to code

28 Government publication:

# = not a government publication
i = international intergovernmental
f = federal/national
a = autonomous or semi-autonomous component
s = state, provincial, territorial, dependent, etc.
m = multistate
c = multilocal
l = local
z = other type of government publication
o = government publication -- level undetermined
u = unknown if item is government publication
| = no attempt to code

29 Conference publication:

0 = not a conference publication
1 = conference publication

| = no attempt to code

30 Festschrift:
- 0 = not a festschrift
- 1 = festschrift
- | = no attempt to code

31 Index:
- 0 = no index
- 1 = index present
- | = no attempt to code

32 Undefined (since 1990) (Earlier records may contain the values 0 or 1)
- # = Undefined
- | = no attempt to code

33 Literary form:
- 0 = not fiction (not further specified)
- 1 = fiction (not further specified)
- c = comic strips
- d = dramas
- e = essays
- f = novels
- h = humor, satires, etc.
- i = letters
- j = short stories
- m = mixed forms
- p = poetry
- s = speeches
- u = unknown
- | = no attempt to code

34 Biography:
- # = no biographical material
- a = autobiography
- b = individual biography
- c = collective biography
- d = contains biographical information
- | = no attempt to code

35-37 Language:
A three-letter code. For example: eng fre ger spa rus ita

(For a full list of codes used in these positions, see the *MARC Code List for Languages*.)

38 Modified record:
- # = not modified
- x = missing characters (because of characters unavailable in MARC character set)
- s = shortened
- d = "dashed-on" information omitted
- r = completely romanized/printed cards in script
- o = completely romanized/printed cards romanized
- | = no attempt to code

39 Cataloging source:

# = national bibliographic agency
c = cooperative cataloging program
d = other sources
u = unknown
| = no attempt to code

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APPENDIX C

Appendix C. Materials Considered

1013	Rolland, J. P., Holloway, R. L., & Fuchs, H. (1995, December). Comparison of optical and video see-through, head-mounted displays, in *Telemanipulator and Telepresence Technologies : 31 October-1 November 1994, Boston, Massachusetts*, Proceedings of SPIE vol. 2351, pp. 293-307 ("*Rolland*").
1013A	Copy of *Rolland*, obtained from the webpage for this article at https://www.spiedigitallibrary.org/conference-proceedings-of-spie/2351/0000/Comparison-of-optical-and-video-see-through-head-mounted-displays/10.1117/12.197322.short from the SPIE Digital Library
1013B	Bibliographic and MARC records for *Telemanipulator and Telepresence Technologies : 31 October-1 November 1994, Boston, Massachusetts*, Proceedings of SPIE vol. 2351, available at https://catalog.lindahall.org/permalink/01LINDAHALL_INST/19lda7s/alma991809043405961 from the online catalog of the Linda Hall Library.
1013C	Profile of the Linda Hall Library, available at http://librarytechnology.org/library/2294.
1013D	Copyright registration record for *Telemanipulator and Telepresence Technologies : 31 October-1 November 1994, Boston, Massachusetts*, Proceedings of SPIE vol. 2351, available at https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?v1=1&ti=1,1&Search%5FArg=Telemanipulator%20and%20Telepresence%20Technologies&Search%5FCode=TALL&CNT=25&PID=kHsYul4cOnaBUPzkg7E-QFTV3qeYt&SEQ=20250323194255&SID=1 from the public catalog of the US Copyright Office.
1013E	Citations to *Rolland*, obtained from Google Scholar.
App A	Hsieh-Yee CV
App B	Parts VII to X of Understanding MARC Bibliographic, available at https://www.loc.gov/marc/umb/um07to10.html

EXHIBIT 1013A

A comparison of optical and video see-through head-mounted displays

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Abstract

One of the most promising and challenging future uses of head-mounted displays (HMDs) is in applications where virtual environments enhance rather than replace real environments. To obtain an enhanced view of the real environment, the user wears a see-through HMD to see 3D computer-generated objects superimposed on his/her real-world view. This see-through capability can be accomplished using either an optical or a video see-through HMD. We discuss the tradeoffs between optical and video see-through HMDs with respect to technological, perceptual, and human factors issues, and discuss our experience designing, building, using, and testing these HMDs.

Keywords: augmented reality, see-through head-mounted displays, superimposition, optics, video cameras

Introduction

One of the most promising and challenging future uses of head-mounted displays (HMDs) is in applications where virtual environments enhance rather than replace real environments. This is often referred to as *augmented reality*. To obtain an enhanced view of the real environment, the user wears a see-through HMD that allows her to see 3D computer-generated objects superimposed on her real-world view. This see-through capability can be accomplished using either an optical or a video see-through HMD, as shown in Figures 1 and 2, respectively.

With optical-see-through HMDs, the real world is seen through semi-transparent mirrors placed in front of the user's eyes, as shown in Figure 1. These mirrors are also used to reflect the computer-generated images into the user's eyes, thereby combining the real- and virtual-world views. With a video see-through HMD, the real-world view is captured with two miniature video cameras mounted on the head gear, as shown in Figure 2, and the computer-generated images are electronically combined with the video representation of the real world.

In the same way that x-ray technology has provided us with a means to see aspects of the inner world of objects and living beings that were unseen before, see-through virtual reality technology provides us with a novel way of visualizing those aspects: the dynamic superimposition of inner worlds registered on their outer parts.

See-through HMDs have been around since the 1960s with Ivan Sutherland's first HMD which was a see-through stereo system with miniature CRTs as the display devices, a mechanical tracker to provide head position and orientation in real time, and a hand-tracking device (Sutherland, 1965).

0-8194-1686-X/94/$6.00

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Most see-through systems that have been designed and/or built are of the optical see-through type.

Examples are the VCASS system (Furness 1986), (Buchroeder et al., 1981), the Tilted Cat HMD (Droessler and Rotier, 1990), and the CAE Fiber-Optic HMD (Barrette, 1992). Several systems have been developed by Kaiser Electronics and McDonnell Douglas, all of them optical see-through systems (Kandebo, 1988).

Figure 1. Optical see-through head-mounted display (Photo courtesy of Kaiser Electro-Optics).

See-through HMDs at the University of North Carolina at Chapel Hill (UNC-CH) have been developed since the 1980s. Applications with both video and optical see-through HMDs have been developed. The driving application for video see-through has been real-time 3D visualization of a human fetus during ultrasound echography (Bajura et al., 1992).[1] An augmented reality system displaying live ultrasound data in real time and properly registered in 3D space within a scanned subject would be a powerful and intuitive tool; it could be used for needle-guided biopsies, obstetrics, cardiology, etc. With the current system, the ultrasound images captured in real time appear to be pasted in front of the patient's body, as shown in Figure 3, rather than fixed within it. Figure 4 shows a recent near-real-time implementation where the fetus is rendered more convincingly within the body (State et al., 1994).

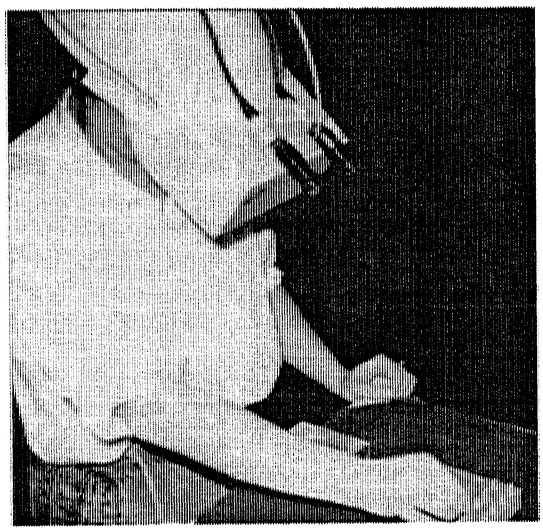

Figure 2. A video see-through head-mounted display.

Another medical application of see-through HMD technology at UNC is a system developed for cranio-facial surgery planning. The eventual goal of this system is to superimpose CT skull data onto the head of the real patient, thereby giving the surgeon "x-ray vision", or the ability to "see" the patient's bone through the soft tissue. The promise of this system is that viewing the data *in situ* will allow surgeons to make better surgical plans because they will be able to see the complex relationships between the bone and soft tissue more clearly. Because of the precision required for this task, however, most of the work in this project has focused on identifying and quantifying the sources of registration error between the real and virtual objects (Holloway, 1994).

[1] To our knowledge, the first video see-through system with walk-around capability in addition to merging of real and synthetic information was developed at UNC-CH. The authors would be grateful for any information on other video STHMD systems.

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An example in the non-medical arena is the work of Caudell and Mizell at Boeing, which uses optical see-through HMD technology to assist workers in the manufacturing assembly of airplanes (Caudell and Mizell, 1992). Combined with head-position sensing and a real-world registration system, the see-through technology in this case allows computer-generated diagrams to be superimposed and stabilized on specific locations of a real-world foamboard. The main difficulty with a complex manufacturing assembly task is the need to have sufficient registration of real and virtual information so that workers may perform their jobs without any risk of errors due to limitations in the apparatus. The successful use of the technology will enable cost reductions and efficiency improvements in several of the manual operations in aircraft manufacturing.

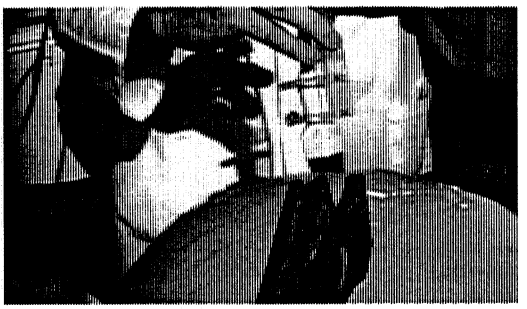

Figure 3. Real-time acquisition and superimposition of ultrasound slice images on a pregnant woman.

Figure 4. More convincing rendering of fetus inside abdomen.

Another example is that of providing assistance with complex maintenance tasks (Feiner et al., 1993). The system developed at Columbia University uses a knowledge-based graphics component in order to aid the user in an end-user laser printer maintenance task. They use graphics superimposed on the laser writer to provide information on various tasks, and use tracker sensors on the printer's moving parts to reflect movements of the real-world objects in the virtual scene.

A more recent application being developed at UNC-CH is the visualization of dynamic 3D anatomy using an optical see-through HMD. This work aims at developing a novel teaching tool to impart better understanding of bone dynamics during radiographic positioning for the radiological science student (Kancherla et al., 1994). In our first prototype, we concentrate on the positioning of the arm about the elbow joint. We use an optical see-through HMD coupled with tracking devices positioned along the arm of the patient to visualize the 3D anatomy directly superimposed on the patient as illustrated in Figure 5. We want to simulate "x-ray vision" as much possible. Therefore, we want the patient's arm to be seen as one would with unaided eyes, but enhanced with computer-simulated bones. This implies that the real scene must be very realistic, the field of view (FOV) should be sufficient to capture the whole arm, and the tracking devices and image-generation system must be fast enough to track motion in real time. The biggest challenge is dynamic registration of the real arm with the virtual bones.

As alluded to with the description of these example applications, the main goal of augmented reality systems is to merge virtual objects into the view of the real scene so that the user's visual system is fooled into perceiving those objects as part of the real environment. Current systems are far from perfect, and system designers typically end up making a number of application-dependent tradeoffs. The goal of this paper is to list and discuss these tradeoffs in order to illustrate under which conditions one might choose one type of see-through system over the other.

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In both systems there are two image sources: the real world and the computer-generated world; these two image sources are to be merged. Optical see-through HMDs take what might be called a "minimally invasive" approach; that is, they leave the view of the real world nearly intact and attempt to augment it by merging a reflected image of the computer-generated scene into the view of the real world. Video see-through HMDs are more invasive in the sense that they block out the real-world view in exchange for the ability to merge the two views more convincingly. The fundamental tradeoff, then, is whether the additional features afforded by the more invasive approach justify the loss of the unobstructed real-world view.

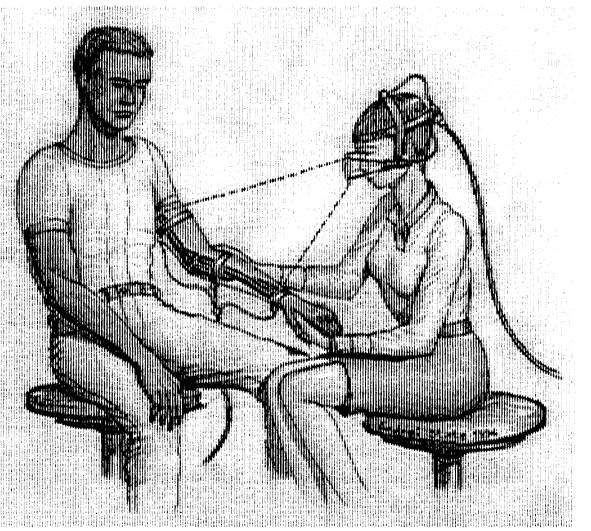

Figure 5. Teaching tool for dynamically superimposing virtual bones onto real arm (drawing by Andrei State).

We discuss the tradeoffs between optical and video see-through HMDs with respect to technological, perceptual, and human factors issues from our experience designing, building, using, and testing these HMDs. Those tradeoffs are also discussed with respect to systems built today, those buildable with today's technology, and those perhaps buildable 5 to 10 years from now. An outline of the issues discussed in the paper is illustrated in Figure 6.

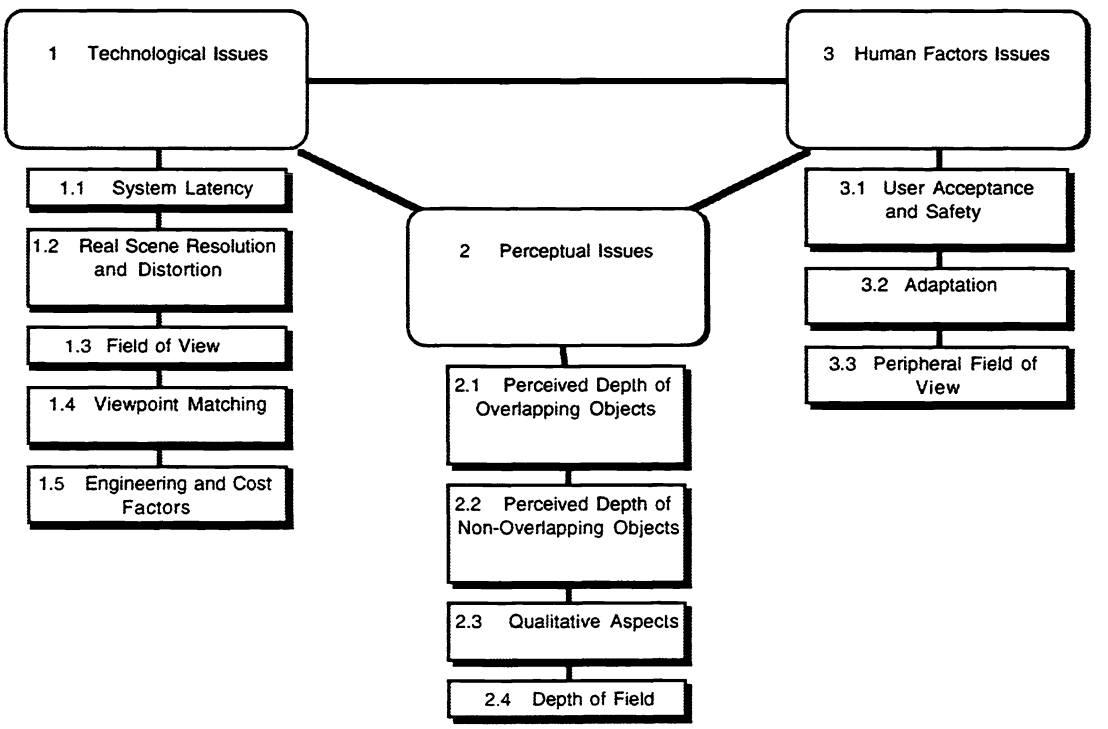

Figure 6. Paper Outline

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1. Technological Issues

The technological issues discussed in this section include latency of the system, resolution and distortion of the real scene, FOV of the see-through device, and engineering and cost factors.

1.1. System Latency

An essential component of see-through HMDs is the capacity to properly register the user's surroundings and the synthetic space. Assuming geometric calibration between tracking and the HMD optics, the major impediment to achieving this registration is the gap in time, referred to as *lag*, between the moment when the HMD position is measured and the moment when the synthetic image for that position is fully completed and presented to the user. Lag is the largest source of registration error in most current HMD systems (Holloway, 1994).

This lag in typical systems is between 60 and 180 ms. The user's head can move significantly during such a period of time, and the discrepancy destroys the illusion of the synthetic objects being fixed in the environment. The synthetic objects "swim" around so much, in fact, that they don't even seem to be part of the environment. Azuma and Bishop demonstrated this swimming effect and show how one can minimize it using predicted HMD positions instead of measured ones (Azuma and Bishop, 1994). They use an optical tracking system augmented with accelerometers and rate gyros and have found that their system can predict well 60 ms ahead, but not well 120 ms ahead.

One of the major advantages of video see-through HMDs is the capability of enforcing registration of the real and synthetic images. In other words, because the system has access to both the real and synthetic images, it can manipulate them in space or in time in order to register them.

The spatial approach to forcing registration in video see-through systems is to correct registration errors by tracking landmark points in the real-world images and registering virtual objects with respect to those. This technique was successfully demonstrated by (Bajura & Neumann, 94) who tracked a pair of red light-emitting diodes (LEDs) placed on two real objects and then registered two virtual objects with respect to them. By tracking more landmarks, better registration of real and virtual objects can be achieved. The problem with this approach is that it is an attempt to register three-dimensional scenes using two-dimensional constraints. If the user rotates his head rapidly or if a real-world object moves, there may be no "correct" transformation for the virtual scene image: one must either allow misregistration of some of the landmarks or perform a non-linear warping of the virtual scene in order to align all of the landmarks (which may induce undesirable distortions of virtual objects). The non-trivial solution to this problem is to increase the speed of the system until scene changes between frames are small and can be approximated with simple 2D transformations.

Enforcing registration in the time domain can be done by introducing delay to the video real-scene images to match the delay of the computer-generated images. This may be done in conjunction with the spatial methods just mentioned. If the delay is too large, however, it may cause sensory conflicts between vision and proprioception, since video images no longer correspond to the real-world scene. Any manual interactions with real objects could suffer as a result. In a similar vein, it is also important to note that the video view of the real scene will normally have some lag due to the time it takes to acquire and display the video images. Thus, video see-through HMDs will normally be slightly delayed with respect to the real world even without adding delay to match the synthetic images. This delay may become even worse if an image-processing step for enforcing registration or performing occlusion is added. The key issue, of course, is whether the delay in the system is too great for the user to adapt to it. This subject has been treated at length in the teleoperation literature; (Held and Durlach, 1987) discuss this problem and give an extensive list of references on the subject.

Systems using optical see-through HMDs have no way to introduce artificial delays to the real scene, so the system needs to be optimized for low latency; that is, less than 60 ms according to (Azuma

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and Bishop, 1994). For any remaining lag, the user can restrain himself to using slow head motions or predictive tracking can be used as described earlier. The advantage, however, of not introducing artificial delays is that real objects will always be where they are perceived to be, and this may be crucial for certain applications.

1.2. Real-Scene Resolution and Distortion

The best real-scene resolution a see-through-device can provide is that reached with the naked eye. This assumes that the see-through device has no image-processing capability. A resolution extremely close to that obtained with the naked eye is easily achieved with an optical see-through HMD because the optical interface to the real world is simply a thin parallel plate positioned between the eyes and the real scene. Such an interface typically introduces only very small amounts of optical aberrations to the real scene. For example, for a real-point object seen through a 2 mm planar parallel plate placed in front of a 4 mm diameter eye pupil, the diffusion spot due to spherical aberration would subtend a 2 10^{-7} arc-minute visual angle for a point object located 500 mm away. Such an aberration is negligible compared to the ability the human eye to resolve a visual angle of 1 minute of arc. Similarly, planar plates introduce very little distortion of the real scene, typically below 1%. There is no distortion for those chief rays that pass the plate parallel to the plate's normal.[2]

In the case of video see-through HMDs, real-scene images are digitized by miniature cameras and converted to an analog signal which is fed to the HMD displays. These images are then magnified by the HMD viewing optics which typically use eyepiece design. The perceived resolution of the real scene can thus be limited by the resolution of either of the three components of the system: the video cameras, the HMD displays, or the HMD viewing optics.

Currently available miniature video cameras typically have a resolution of 720x480, which is also near the resolution limit of the miniature displays currently used in HMDs[3]. Both the miniature displays and the video cameras currently limit the resolution of most systems.

In addition, eyepiece designs have also been recognized for many decades to be extremely limited in optical quality due to their fairly large FOVs and their need for an exit pupil size large enough to accommodate the size of the pupils of the person's eyes. Thus, even with higher resolution cameras and displays, video see-through HMDs may remain limited in their ability to provide a real-scene view of high resolution if conventional eyepiece designs continue to be used.

A new technology, referred to as *tiling*, may overcome the current limitations of conventional eyepiece design (Kaiser, 94). The idea is to use multiple narrow-FOV eyepieces coupled with miniature displays to completely cover (or *tile*) the user's FOV. Because the individual eyepieces now have a fairly narrow FOV, high image quality can be achieved. The challenge is in the assembly process and in rendering seamless views from multiple displays.

Theoretically, distortion is not a problem in video see-through systems since the cameras can be designed to compensate for the distortion of the optical viewer, as demonstrated by Edwards et al. (1993). However, if the goal is to merge real and virtual information, as in ultrasound echography, having a warped real scene increases the complexity of the synthetic image generation significantly (State et al., 1994). An alternative is to use ultra-low distortion cameras, merge unprocessed real scenes with virtual scenes, and warp the merged images to compensate for the distortion of the HMD viewing optics as a last step.

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[2] The chief ray is defined as a ray that passes through a point in the FOV and through the center of the pupils of the sytem. The exit pupil in an HMD is the entrance pupil of the human eye.

[3] The number of physical elements is typically 720 x 240, and one uses signal processing to interpolate between lines to get 720 x 480.

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The need for high real-scene resolution is highly task-dependent. Demanding tasks such as surgery or engineering training, for example, may not be able to tolerate any loss in real-scene resolution. Current video see-through systems are seriously limited in terms of resolution, but with new tiling technologies and the growing availability of high-resolution flat-panel displays, video see-through HMDs may match the resolution of the human visual system five years from now.

1.3. Field of View

Another challenging issue is that of providing the user with a large FOV. What we refer to here is the monocular FOV at a given time, head position and orientation, unless otherwise specified. The binocular FOV is a function of the monocular FOV's overlap and can be calculated for each system based on its geometry. For 100% overlap, the binocular FOV is equal to the monocular FOV, while for no overlap, it is twice the monocular FOV. A decrease in binocular overlap, however, results in a decrease of the binocular fusion zone where stereo vision is possible. For most applications, having a larger binocular FOV means that fewer head movements are required to perceive an equivalently large scene. However, in many cases, one would prefer to have a large binocular FOV without trading off the amount of binocular overlap that is necessary for stereo vision. In those cases, the monocular FOV itself must be optimized. We believe that a large FOV is especially important for tasks that require grabbing and moving objects and that it provides increased situation awareness when compared to narrow FOV devices. We will use the term *overlay FOV* to describe the merged virtual and real FOV.

Optical see-through HMDs typically provide from 20° to 60° overlay FOV via the semi-transparent mirror placed in front of the eyes, a value which may appear somewhat limited. Larger FOVs have been obtained, up to 82.5 x 67 degrees (Welch and Shenker, 1984), at the expense of reduced brightness, increased complexity, and massive, expensive technology. Optical see-through HMDs, however, have been designed open enough that the user can use his/her peripheral vision around the device, thus increasing the total real-world FOV to numbers that match closely one's natural FOV. An annulus of obstruction usually results from the mounts of the thin see-through mirror similar to the way that our vision may be partially occluded by a frame when wearing eye- or sun-glasses.

Video see-through HMDs, on the other hand, can provide as large a see-through FOV as can be displayed with the viewing optics. Typical values range from 20° to 90°. However, because current HMDs used in video see-through are of the opaque type where the peripheral FOV of the user is occluded, the effective real-world FOV is often smaller than in optical see-through systems. We found in a recent human-factors study using a video see-through system that users needed to perform larger head movements to scan an active field of vision required for a task than when they used the unaided eye (Rolland at al., 1994). We predict that the need to make larger head movements would not arise as much with see-through HMDs with large peripheral FOVs.

An increase in peripheral FOV in video see-through systems can be accomplished in two ways: 1) in a folded optical design as used for optical see-through HMDs but with an opaque mirror instead of a semi-transparent mirror; 2) in a non-folded design but with non-enclosed mounts, which calls for innovative opto-mechanical design since heavier optics have to be supported than in either optical or folded video see-through. Folded systems only require a thin mirror in front of the eyes, and the heavier optical components are placed around the head. The tradeoff with folded systems, however, is a significant reduction in the overlay FOV (as experienced with optical see-through HMDs).

Most current high-resolution HMDs achieve their higher resolution at the expense of a reduced FOV. That is, they use smaller, high-resolution CRTs and optics with less magnification in order to achieve higher angular resolution, but the resulting FOV may be too narrow for many applications. A solution to this problem is again, perhaps, to move towards tiling techniques to improve resolution without trading FOV.

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These techniques also bring new practical and computational challenges that need to be confronted. In particular, for a tiled video see-through system, one either needs multiple, correlated cameras for each eye, or an ultra-wide-FOV camera for each eye whose image can then be segmented somehow. Thus, while tiling is a promising approach for wide-FOV, high-resolution HMDs, it also introduces some challenging technical problems for use in video see-through HMD systems.

1.4 Viewpoint Matching

The viewpoint of a camera or eye is equivalent to the center of projection used in the computer graphics model and is taken here to be the center of the entrance pupil of the eye or camera. A problem with video see-through HMDs is that the straightforward method of mounting the cameras introduces an error in the viewpoints for the real-world images.

The straightforward method of mounting the cameras on a video see-through HMD is to separate them by the appropriate interpupillary distance (IPD) and mount them on the front or top of the HMD, or to mount them on the side of the HMD, in which case they will be separated by more than the IPD. The problem with this approach is that the viewpoint of the camera does not correspond to the viewpoint of the eye, which introduces a shift in the perceived scene for each eye, which may lead to perceptual anomalies (see the Human Factors section for more on this).

Since the camera cannot be physically placed at the actual eyepoint, one alternative is to use mirrors to fold the optical path (much like a periscope) in order to make the camera viewpoint correspond to the real eyepoint. The following figure illustrates this idea.

While this approach solves the viewpoint-shift problem, it increases the optical path length which reduces the field of view (for the same reason that optical see-through HMDs tend to have smaller fields of view). Thus, video see-through HMDs must either trade their large FOV for correct real-world viewpoints or require the user to adapt to the shifted viewpoints (more on this later).

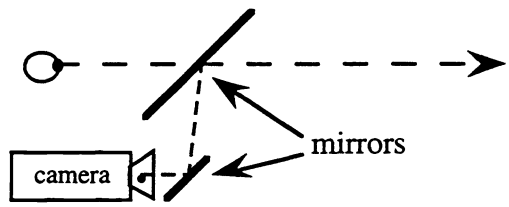

Figure 7. Folded path to make viewpoints for real and virtual scenes optically identical

1.5. Engineering and Cost Factors

Simple HMD designs suffer from low resolution, limited FOV, poor ergonomic design, and heavy weight. To overcome any of these limitations, one must face new challenges and further tradeoffs. A good ergonomic design implies that either the HMD is light enough that it does not weigh much more than a pair of eyeglasses or the HMD folds around the user's head so that the center of gravity of the device falls more or less near the center of rotation of the head (Rolland, 1994). This assures maximum comfort and usability. Reasonably light HMD designs currently suffer very narrow FOVs, on the order of 20 degrees. As far as we know, there are currently no large FOV see-through HMDs of any type that are comparable in weight to a pair of eyeglasses.

With optical see-through, the folding can be accomplished with either an on-axis or an off-axis design. Off-axis designs are not only more elegant but also by far more attractive since they free the user from seeing ghost images that plague current on-axis designs. The reason we cannot buy off-axis designs is that very few prototypes have been built and those that have been built have been classified. Moreover, off-axis systems are difficult to design and have turned out to be hard to build (Shenker, 1994). Moreover, they are usually more expensive to design and build due to the cost of off-axis and/or non spherical optical elements that come with such systems. A non-classified off-axis design was designed by Rolland (1994) at UNC-CH. Multiple factors, including cost, have so far

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prohibited us from building the first prototype.

Video see-through systems usually do not use a folded design and therefore suffer from a lack of peripheral FOV, since they use rigid helmets to hold the optics and displays in front of the user's eyes. With tiling techniques, no folding is required since the large FOV that drove the need for complex optics, and thus that of folding it, is now created by multiple narrow FOV devices that are a lot simpler optically. It is an open question whether such devices can be successfully built. Moreover, the cost of such a device may be significantly higher due to the need for multiple miniature high-resolution displays, precision alignment of the displays, and image-generation hardware to drive them.

Since their beginning, high resolution HMDs have been CRT-based. Early systems were even monochrome but color CRTs using color wheels or frame sequential color have been fabricated and incorporated into HMDs (Allen, 1993). In the next five to ten years, we predict that high-resolution color flat-panel displays will be the first choice for HMDs. It has been predicted for years that CRTs would become obsolete, yet they are still used today. The reason for renewed optimism is the support given to the development of flat panel technologies by government agencies such as ARPA and the existence of a market for high-resolution miniature displays in video camcorders.

2. Perceptual Issues

The ultimate system is one that provides quantitative and qualitative visual representation of scenes that conforms to that given by the real world. This includes 1. accuracy and precision of depth, 2. accuracy and precision of size, of real and virtual objects in a scene, and 3. an unobstructed peripheral FOV which is important for many tasks from situation awareness to simple manipulation of objects and accessories. In this section, perceived depth and size, qualitative aspects of the real scene, and depth of field issues will be discussed. Peripheral FOV issues will be discussed in the human factors section.

Perceived depth and size of objects are important because they determine the 3D space they occupy. Perceived depth will be accurate and precise if objects appear on average at the location predicted by the computational model used to position virtual objects. Perceived depth will be precise if objects appear within a small spatial zone around that average location. A strong component of rendering depth accurately is occlusion of overlapping objects. Because the ability to perform occlusion is an important issue of comparison between optical and video see-through HMDs, we discuss it first.

2.1. Perceived Depth of Overlapping Objects

One of the most important differences between these two technologies is how they handle the depth cue known as *occlusion* (or interposition). In real life, an opaque object can block the view of another object so that part or all of it is not visible. While there is no problem in making computer-generated objects occlude each other in either system, it is considerably more difficult to make real objects occlude virtual objects and vice versa. Moreover, occlusion is a strong monocular cue to depth perception and may be required in certain applications.

In both systems, any attempt to do occlusion between the real and virtual scenes requires a depth map of both scenes. A depth map of the virtual scene is usually available (for *z*-buffered image generators), but a depth map of the real scene is a much more difficult problem. While progress in this area is being made (Tomasi & Kanade 1991),(Laveau & Faugeras 1994), the problem is far from solved. Thus, occlusion cues for either type of display will be limited by the state of the art in this area. We can now move on to a discussion of the tradeoffs with respect to occlusion for each type of see-through HMD.

Assuming the system has a depth map of the real environment, video see-through HMDs are

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perfectly positioned to take advantage of this information. They can, on a pixel-by-pixel basis, selectively block out the view of either scene or even blend them to minimize edge artifacts. One of the chief advantages of video see-through HMDs is that they handle this problem so well.

The situation for optical see-through HMDs is more complex. Existing optical see-through HMDs blend the two images with beam splitters, which blend the real and virtual images uniformly throughout the FOV. Normally, the only control the designer has is the amount of reflectance versus transmittance of the beam splitter, which can be chosen to match the brightness of the displays with the expected light levels in the real-world environment. If the system has a model of the real environment, it is possible to cause real objects to occlude virtual ones simply by not drawing the occluded parts of the virtual objects. The only light will then be from the real objects, giving the illusion that they are occluding the virtual ones.

This technique is currently used by CAE Electronics in their flight simulator: When the pilot looks out the window, s/he sees computer-generated objects. If s/he looks inside the cockpit, however, the appropriate pixels of the computer-generated image are masked so s/he can see the real instruments. They keep the room fairly dark so that this technique will work (Barrette, 1992). Tom Caudell and David Mizell from Boeing Seattle are also using this technique; they refer to it as "fused reality" (Mizell, 1994).

While optical see-through HMDs can allow real objects to occlude virtual objects, the reverse is not easy to do since normal beam splitters have no way of selectively blocking out the real environment. There are at least two possible solutions to this problem, neither of them perfect. The first solution is to control the light levels in the real environment and to use displays that are bright enough so that the virtual objects mask the real ones by reason of contrast. This approach is used in the flight simulator just mentioned for creating the virtual instruments. This may be a solution for certain applications, but probably not for all. A possible second solution would be to locally attenuate the real-world view by using an addressable filter device placed on the see-through mirror. The problem with this approach is that the user does not focus on the beam splitter, but rather on the virtual image it creates. Thus, any blocking done at the beam splitter will be out of focus, which might lead to odd visual effects.

A final possibility is that some applications may work acceptably without properly rendered occlusion cues. That is, in some cases, the user may be able to use other depth cues, such as head-motion parallax, to resolve the ambiguity caused by the lack of occlusion cues.

2.2. Perceived Depth of Non-Overlapping Objects

In the case of non-overlapping objects, one may resort to depth cues other than occlusion. These include familiar sizes, stereopsis, perspective, texture, and motion parallax. A psychophysical investigation of perceived depth using stereopsis and perspective as the visual cues to depth in a virtual environment is given in (Rolland et al., 1994). The apparatus consisted of an optical see-through bench prototype HMD. Some of the main results were that a systematic, but relatively small shift, in perceived depth from predicted values was found, but that the precision of the measures varied significantly across subjects. Data were only reported for three subjects, and further data need to be acquired to confirm those findings. Some measures of perceived size were conducted by Roscoe and colleagues in see-through HMDs and a main result was that objects seemed to be perceived smaller than they actually were (Roscoe, 1984, 1991). It is an experimental question whether current computational models correctly predict perceived depth and sizes in virtual environments.

For video see-through HMDs, the problems with viewpoint and FOV matching between the displays and the cameras can introduce additional errors in perceived depth. Although it is possible in theory to eliminate such mismatches, real systems are often limited by the available technology and therefore leave it to the user to adapt to the discrepancy. The effect of viewpoint mismatches will be

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discussed in the section on human factors.

2.3. Qualitative Aspects

The representation of virtual objects, and in some cases of real objects, is altered by see-through devices. Aspects of perceptual representation include the shape of objects, their color, brightness, contrast, shading, texture, and level of detail. In the case of optical see-through HMDs, the real objects are seen basically unaltered since they are only perceived through an ultra-thin plate of glass, as mentioned earlier.

Other aspects of objects' representation besides brightness attenuation and distortion may be altered in video see-through HMDs. Our experience with at least one system is that real objects' color and brightness are altered along with the loss in texture and levels of detail due to the limited resolution (this includes spatial, luminance, and color resolution) of the miniature video cameras and wide angle optical viewer present in the system (Rolland et al., 1994). This is perhaps resolvable with improved technology but currently limits the ability of the HMD user to perceive real objects as they would appear with unaided eyes. We do not foresee a breakthrough in the next five years, but perhaps in the next ten years.

For optical see-through systems, folding the optical path by using a semi-transparent mirror is necessary because it is the only configuration that leaves the real scene almost unaltered. A thin folding mirror will introduce a small shift in depth of real objects equal to $e(n-1)/n$ where e is the thickness of the plate and n is its index of refraction. This is in addition to a small amount of distortion of the scene at the edges of the FOV, as discussed earlier.

2.4. Depth of Field

One important property of the human visual system not yet addressed is *depth of field.* Depth of field refers to the range of distances from the eye in which an object appears to be in focus without the need for a change in eye accommodation. If an object is accurately focused monocularly, other objects somewhat nearer and further away are also seen clearly without any change in accommodation. Still nearer or further away objects are blurred. Depth of field reduces the necessity for precise accommodation, but is markedly influenced by the diameter of the pupil. The larger the pupil, the smaller the depth of field. For a 2 mm and 4 mm pupil, the depth of field is +/- 0.06 and +/- 0.03 diopters, respectively. For a 4 mm pupil, for example, such a depth of field translates as a clear focus from 0.94 to 1.06 meter for an object 1 meter away, and to 11 meters to 33 meters for an object 17 meters away (Campbell, 1957; Moses, 1970). The important point to note is that accommodation may play an important role only at close working distance where depth of field is narrow.

With video see-through systems, the miniature cameras used for acquiring the real scene images must provide a depth of field equivalent to the required working distance for a task. For a large range of working distances, the camera may need to be focused at the middle working distance. For closer distances, the small depth of field may require an autofocus instead of a fixed-focus camera.

With optical see-through systems, the available depth of field for the real scene is essentially that of the human visual system, but for a larger pupil than would be accessible with unaided eyes. This can be explained by the brightness attenuation of the real scene by the semi-transparent mirror. As a result, the pupils are dilated (we assume here that the real and virtual scenes are matched in brightness). Therefore, the effective depth of field will be slightly less than with unaided eyes. This is only a problem if the user is working with nearby objects and the virtual images are focused outside of the depth of field required for nearby objects. With current displays, the virtual images suffer so much from blur due to the poor resolution of the displays themselves that the need to accommodate at different planes, for real and virtual objects to be seen clearly, may not even come into play.

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Since retinal images are never truly sharp, the visual system is constantly processing somewhat blurred images and tends to tolerate blur up to the point at which essential detail is obscured. This tolerance for blur extends the apparent depth of field considerably, so that the eye may be as much as +/-0.25 diopters out of focus without stimulating accommodative change (Moses, 1970). From this observation, convergence and accommodation in a HMD may not be as decoupled as one theoretically would predict. This would occur at the expense of more blurry images that may be properly handled by the visual system. Whether these factors affect depth perception is worth further investigation.

3. Human Factors Issues

Some of the issues discussed in this section currently have few quantitative proofs because too few human factors studies have been conducted with VR technology in general, and even less with see-through VR technology. We shall therefore offer our opinions based on our experience.

3.1. User Acceptance and Safety

A fair question for either type of technology is "will anyone actually wear one of these devices for extended periods?" The answer will doubtless be application- and technology-specific, but will probably boil down to the issue of whether the advanced capabilities afforded by the technology offset the problems induced by the encumbrance and sensory conflicts associated with it. In particular, video see-through HMDs may meet with resistance in the workplace since they take away the direct real-world view in order to augment it; there is an issue of trust that may be difficult to overcome for some users. Moreover, current problems with low resolution and camera/eye viewpoint mismatches will tend to push the acceptance threshold further into the future for video see-through systems.

The problem is exacerbated in safety-critical applications. A key difference in such applications may turn out to be the failure mode of each technology. A failing in technology in the case of optical see-through may leave the subject without any computer-generated images but still with the real world view. In the case of video see-through, a failing in technology may leave the user with complete suppression of the real-world view, as well as the computer-generated view. Such a loss may be unacceptable in many applications for reasons of safety and liability.

3.2. Adaptation

When a system does not offer what the user ultimately wants, two paths may be taken: 1) improving on the current technology, or 2) studying the ability of the human system to adapt to an imperfect technological unit and developing adaptation training when appropriate. This is possible because of the astonishing ability of the human visual and proprioceptive systems to adapt to new environments, as has been shown in multiple studies on adaptation (Rock, 1966).

We recently conducted a study of adaptation to visual displacement in see-through HMDs (Rolland & Biocca et al., 1994). Users see the real world through two cameras which are located 62 mm higher, and 165 mm forward from their natural eyepoints. Subjects showed evidence of perceptual adaptation to sensory disarrangement during the course of the study. This revealed itself as improvement in performance over time while wearing the see-through HMD and as negative aftereffects once they removed it. More precisely, the negative aftereffect manifested itself clearly as a large overshoot in a depth pointing task, as well as an upward translation in a lateral pointing task after wearing the HMD.

The presence of negative after-effects has some potentially disturbing practical implications for the diffusion of see-through HMDs. Some of the intended earlier users of these HMDs are surgeons and

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other individuals in the medical profession. Hand-eye sensory recalibration for highly skilled users like surgeons could have potentially disturbing consequences if the surgeon were to enter surgery within some period after use of a HMD. It is an empirical question how long the negative aftereffects might persist, and whether a program of gradual adaptation (Welch, 1994) or dual adaptation (Welch, 1993) might minimize the effect altogether. In any case, any shift in the camera eyepoints need to be minimized as much as possible to facilitate any adaptation process that is taking place.

3.3. Peripheral FOV

Given that peripheral vision can be provided for both optical and video see-through systems, the next question is whether it is used as effectively for both systems. In optical see-through, there is almost no transition or discrepancy between the real scene captured by the see-through device and the peripheral vision seen on the side of the device.

For video see-through, the peripheral FOV can be also captured by video cameras or may be provided by letting the user see around the device, as with optical see-through. Especially in the latter case, it remains to be seen whether the difference in presentation of the superimposed real scene and the peripheral real scene will cause discomfort or provide conflicting cues to the user.

Conclusion

We have presented a comparison of optical and video see-through head-mounted displays. In our opinion, the most important issues are system latency, occlusion, and the fidelity of the real-world view. Optical see-through systems offer an essentially unhindered view of the real environment; they also provide an instantaneous real-world view which assures that visual and proprioception information is synchronized. Video systems give up the unhindered view in return for improved ability to render occlusion cues; the issue of how to really perform occlusion is far from solved, however, and remains an active area of research. Video see-through systems can also guarantee registration of the real and virtual scenes at the expense of a mismatch between vision and proprioception, which may or may not be perceived as a penalty if the human observer is able to adapt to such a mismatch. Clearly, there is no "right" system for all applications: each of the tradeoffs discussed in this paper must be examined with respect to the planned application and available technology to determine which type of system is most appropriate.

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