

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Amazon.com, Inc. and Amazon.com Services LLC,

Petitioner

v.

LightGuide Inc.,

Patent Owner.

IPR2024-00141

U.S. Patent No. 7,515,981

DECLARATION OF JAMES L. MULLINS. Ph.D.

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I. INTRODUCTION

I, James L. Mullins, am above the age of majority and hereby declare under penalty of perjury:

1. I have been retained by counsel for Petitioners Amazon.com, Inc. and Amazon.com Services LLC to analyze and opine on the authenticity and public accessibility of certain documents referenced herein.

2. I am presently Dean Emeritus of Libraries and Esther Ellis Norton Professor Emeritus at Purdue University. My career as a professional and academic/researcher spans more than forty-four years, including library positions at Indiana University, Villanova University, Massachusetts Institute of Technology, and Purdue University. Appendix B is a true and correct copy of my curriculum vitae describing my background and experience.

3. In 2018, I founded the firm Prior Art Documentation Librarian Services, LLC, now located at 205 Saint Cuthbert, Williamsburg, VA 23188. Further information about my firm, Prior Art Documentation Librarian Services, LLC (PADLS), is available at www.priorartdoclib.com.

4. For my services in connection with this case, I bill at my usual and customary hourly fee of \$275.00. I have no stake in the outcome of this proceeding or any related litigation or administrative proceedings, and my compensation in no way depends on the substance of my testimony or the outcome of this proceeding.

5. As part of my preparation for completing this report, I have reviewed and considered the materials identified in this report.

II. QUALIFICATIONS

6. I received a Bachelor of Arts degree in History, Religion and Political Science in 1972 as well as a Master of Arts degree in Library Science in 1973, both from the University of Iowa. I received my Ph.D. in Academic Library Management in 1984 from Indiana University. Over forty-four years, I have held various positions, and am considered a leader in the field of library and information sciences.

7. I am currently Dean Emeritus of Libraries and Esther Ellis Norton Professor Emeritus at Purdue University, 2018 – present. I was previously employed as follows:

i) Dean of Libraries and Professor and Esther Ellis Norton Professor, Purdue University, West Lafayette, IN, 2004 – 2017;

ii) Assistant/Associate Director for Administration, Massachusetts Institute of Technology (MIT) Libraries, Cambridge, MA, 2000 – 2004;

iii) University Librarian and Director, Falvey Memorial Library, Villanova University, Villanova, PA, 1996 – 2000;

iv) Director of Library Services, Indiana University South Bend, South Bend, IN, 1978 – 1996;

v) Part-time Instructor, School of Library and Information Science, Indiana University, Bloomington, IN, 1979 – 1996;

vi) Associate Law Librarian, and associated titles, Indiana University School of Law, Bloomington, IN, 1974 –1978;

vii) Catalog Librarian, Assistant Professor, Georgia Southern College (now University), Statesboro, GA, 1973 – 1974.

8. I am a member of the American Library Association (“ALA”), where I served as the chair of the Research Committee of the Association of College and Research Libraries (“ACRL”). My service to ALA included service on the editorial board of the most prominent library journal, *College and Research Libraries*. I also served on the Standards Committee, College Section of the ACRL, where I was instrumental in developing a re-issue of the *Standards for College Libraries* in 2000.

9. I am an author of numerous publications in the field of library science and have given presentations in library sciences at national and international conferences. During more than forty-four years as an academic librarian and library science scholar, I have gained extensive experience with techniques and systems for cataloging and indexing printed materials in the library setting, including catalog records and online library management systems built using Machine-Readable Cataloging (“MARC”) standards. As an academic library administrator, I have had responsibility to ensure that students were educated to identify, locate, assess, and

integrate information garnered from research library resources. I have also facilitated the research of faculty colleagues either directly or through the provision of and access to the requisite print and/or digital materials and services at the universities where I worked.

10. Based on my experience identified above and detailed in my curriculum vitae, which is attached hereto as Appendix B, I consider myself to be an expert in the field of library science and academic library administration. I have previously offered my opinions on the public accessibility and authenticity of documents in over 118 cases. I have been deposed in one case.

III. LEGAL STANDARDS

11. I am not a lawyer. My understanding of the legal standards to apply in reaching the conclusions in this declaration is based on discussions with counsel for Petitioner, my experience applying similar standards in other patent-related matters, and my reading of the documents related to this proceeding. In preparing this declaration, I have tried to faithfully apply these legal standards to the authenticity of the documents referenced herein and whether, when, and how these documents were publicly accessible.

A. Authentication

12. I have been informed by counsel and understand that an item is considered authentic if there is sufficient evidence to support a finding that the item

is what it is claimed to be by the proponent of the item. I have also been informed that authenticity can be established based on the properties of the item itself, such as the appearance, content, substance, internal patterns, or other distinctive characteristics of the item.

B. Public Accessibility

13. I have been informed by counsel and understand that a given reference qualifies as publicly accessible if it was disseminated or otherwise made available such that persons interested and ordinarily skilled in the relevant subject matter could locate it through the exercise of ordinary diligence.

14. I have been informed by counsel and understand that the determination of public accessibility under the foregoing standard rests on a case-by-case analysis of the facts particular to an individual publication. However, I also understand that one way that public accessibility can be shown is if a publication is cataloged and indexed by a library such that a person interested in the relevant subject matter could locate it. In other words, I understand that cataloging and indexing by a library, such that a person interested in the relevant subject matter could locate the reference, is sufficient to render it publicly accessible, though there are other ways that a given reference may qualify as publicly accessible. One manner of sufficient indexing is indexing according to subject matter. I have been informed by counsel and understand that it is not necessary to prove someone actually looked at the reference

in order to show it was publicly accessible by virtue of a library's cataloging and indexing thereof. I understand that cataloging and indexing of a particular printed publication can indicate that the publication is publicly accessible.

15. I also understand that there are other ways that a given reference may be deemed publicly accessible, including where that reference is cited by others in the field.

C. The Critical Date

16. I have been informed by counsel that for the purposes of this declaration I should consider evidence of public accessibility prior to June 1, 2005. As described further below, I have concluded that each of the references discussed herein was publicly accessible, including to a Person of Ordinary Skill in the Art, prior to June 1, 2005.

D. The Person of Ordinary Skill in the Art

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

18. In addition, I have been informed by counsel that as relevant to these proceedings, the POSA would have the skills of one or more individuals with

experience in the fields of interactive computer applications. These individuals would have at least a four-year degree in electrical engineering, mechanical engineering, computer science, or a closely related field, and at least a year of experience working in interactive computer applications. Lack of work experience can be remedied by additional education, and vice versa.

IV. BACKGROUND OF LIBRARY CATALOG RECORDS AND OTHER RESOURCES

19. Some background on MARC formatted records, Online Computer Library Center (“OCLC”), and WorldCat is helpful to understand the library catalog records discussed in this report. I am fully familiar with the library cataloging standard known as the MARC standard, which is an industry-wide standard method of storing and organizing library catalog information.¹ MARC practices have been consistent since the MARC format was developed by the Library of Congress in the 1960s, and by the early 1970s became the U.S. national standard for disseminating bibliographic data. By the mid-1970s, MARC format became the international standard, and persists through the present. A MARC-compatible library is one that has a catalog consisting of individual MARC records for each of its items. The

¹ The full text of the standard is available from the Library of Congress at <http://www.loc.gov/marc/bibliographic/>.

underlying MARC format underpins the online public access catalog (“OPAC”) that is available to library users to locate a particular holding of a library. Today, MARC is the primary communications protocol for the transfer and storage of bibliographic metadata in libraries.² The MARC practices discussed below were in place during the time frames relevant to the documents referenced herein.

20. OCLC is a not-for-profit worldwide consortium of libraries. Similar to MARC standards, OCLC’s practices have been consistent since the 1970s through the present. Accordingly, the OCLC practices discussed below were in place during the time frame discussed in my opinions section. 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

² Almost every major library in the world uses a catalog that is MARC-compatible. *See, e.g.*, Library of Congress, *MARC Frequently Asked Questions (FAQ)*, <https://www.loc.gov/marc/faq.html> (last visited Jan. 24, 2018). “MARC is the acronym for MACHine-Readable Cataloging. It defines a data format that emerged from a Library of Congress-led initiative that began nearly forty years ago. It provides the mechanism by which computers exchange, use, and interpret bibliographic information, and its data elements make up the foundation of most library catalogs used today.” MARC is the ANSI/NISO Z39.2-1994 (reaffirmed 2009) standard for Information Interchange Format.

scientific, literary and educational knowledge and information.”³ Among other services, OCLC and its members are responsible for maintaining the WorldCat database (<http://www.worldcat.org/>), used by libraries throughout the world.

21. Libraries worldwide use the MARC format for catalog records. MARC-formatted records include a variety of subject access points based on the content of the document being cataloged. A MARC record for a particular work comprises 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. For example, a work’s title is recorded in field 245, the primary author of the work is recorded in field 100, a work’s International Standard Book Number (“ISBN”) is recorded in field 020, and the work’s Library of Congress call number (assigned by Library of Congress) is recorded in field 050. Some fields can contain subfields, which are indicated by letters. For example, a work’s publication date is recorded in field 260 under the subfield “c.”

22. The MARC Field 040, subfield “a,” identifies the library or other entity that created the catalog record in the MARC format. MARC Field 008 identifies the date when this first MARC record was created.

³ OCLC Online Computer Library Center, Inc., Amended Articles of Incorporation of OCLC Online Computer Library Center, Inc., Third Article (OCLC, Dublin, Ohio) Revised June 23, 2017, <https://www.oclc.org/content/dam/oclc/membership/articles-of-incorporation.pdf>.

23. MARC records also include several fields that include subject matter classification information. An overview of MARC record fields is available through the Library of Congress at <http://www.loc.gov/marc/bibliographic/>. For example, 6XX fields are termed “Subject Access Fields.”⁴ Among these, for example, is the 650 field; this is the “Subject Added Entry - Topical Term (R)” field. See <http://www.loc.gov/marc/bibliographic/bd650.html>. The 650 field is a “[s]ubject added entry in which the entry element is a topical term.” *Id.* The 650 field entries “are assigned to a bibliographic record to provide access according to generally accepted thesaurus-building rules (e.g., *Library of Congress Subject Headings* (LCSH), *Medical Subject Headings* (MeSH)).” *Id.* Thus, a researcher can easily discover material relevant to a topic of interest with a search using the terms employed in MARC Fields 6XX.

24. Further, MARC records include call numbers, which themselves include a classification number. For example, the 050 field is dedicated as the “Library of Congress Call Number (R)”⁵ as assigned by the Library of Congress. A defined portion of the Library of Congress Call Number is the classification number, and “source of the classification number is *Library of Congress Classification* and

⁴ See <http://www.loc.gov/marc/bibliographic/bd6xx.html>.

⁵ See <http://www.loc.gov/marc/bibliographic/bd050.html>.

the *LC Classification-Additions and Changes*.” *Id.* Thus, included in the 050 field is a subject matter classification. As an example: TK5105.59 indicates books on computer networks - security measures. When a local library assigns a classification number, most often a Library of Congress derived classification number created by a local library cataloger or sometimes a Dewey Decimal classification number for example, 005.8, computer networks - security measures, it appears in the 090 field. In either scenario, the MARC record includes a classification number in the call number field that represents a subject matter classification.

25. The 9XX fields, which are not part of the standard MARC 21 format⁶, were defined by OCLC for use by the Library of Congress, processing or holding notes for a local library, and for internal OCLC use. For example, the 955 field is reserved for use by the Library of Congress to track the progress of a new acquisition from the time it is submitted for Cataloging in Publication (“CIP”) review until it is published and fully cataloged and publicly available for use within the Library of Congress. Fields 901-907, 910, and 945-949 have been defined by OCLC for local use and will pass OCLC validation. Fields 905 or 910 are often used by an individual library for internal processing purposes, for example the date of cataloging and/or the initials of the cataloger.

⁶ See <https://www.oclc.org/bibformats/en/9xx.html>.

26. *WorldCat* is the world's largest public online catalog, maintained by the OCLC, a not-for-profit international library consortium, and built with the records created by the thousands of libraries that are members of OCLC. OCLC provides bibliographic and abstract information to the public based on MARC-compliant records through its OCLC *WorldCat* database. *WorldCat* requires no knowledge of MARC tags and codes and does not require a login or password. *WorldCat* is easily accessible through the World Wide Web to all who wish to search it; there are no restrictions to be a member of a particular community, etc. The date a given catalog record was created (corresponding to the MARC Field 008) appears in some detailed *WorldCat* records as the Date of Entry but not necessarily all. *WorldCat* does not provide a view of the underlying MARC format for a specific *WorldCat* record. In order to see the underlying MARC format, the researcher must locate the book in a holding library listed among those shown in *WorldCat*, and search the OPAC of a holding library. Whereas *WorldCat* records are widely available, the availability of library-specific MARC formatted records varies from library to library. When a specific library wishes to make the underlying MARC format available, there will be a link from the library's OPAC display, often identified as a MARC record or librarian/staff view.

27. When a MARC record is created by the Library of Congress or an OCLC member institution, the date of creation for that record is automatically

populated in the fixed field (008), with characters 00 through 05 in year, month, day format (YYMMDD).⁷ Therefore, the MARC record creation date reflects the date on which the publication associated with the record was first cataloged. Thereafter, the local library's computer system may automatically update the date in field 005 every time the library updates the MARC record (e.g., to reflect that an item has been moved to a different shelving location within the library, or a reload of the bibliographic data with the introduction of a new library management system that creates and manages the OPAC).

A. Monograph Publications

28. Monograph publications are written on a single topic, presented at length, and distinguished from an article. They include books, dissertations, proceedings of a conference, and technical reports. A library typically creates a catalog record when the monograph is acquired by the library. First, it will search the OCLC to determine if a record has already been created by the Library of Congress or another OCLC institution.

29. If a record is found in OCLC, the record is downloaded into the library's management system that typically includes the OPAC. Once the item is downloaded into the library's management system, the library adds its identifier to

⁷ Some of the newer library catalog systems also include hour, minute, second (HHMMSS).

the OCLC database so when a search is completed on *WorldCat*, the library will be indicated as possessing the publication. Once a record is created in a library's management system, it is searchable and viewable through the library's OPAC, typically by author, title, and subject heading, at that library and from anywhere in the world through the internet by accessing that library's OPAC. The OPAC also connects with the circulation function of the library, which typically indicates whether the record is available, in circulation, etc., with its call number and location in a specific departmental/disciplinary library, if applicable. The OPAC not only provides immediate bibliographic access on-site, but it also facilitates the interlibrary loan process, which is when one publication is loaned from one library to another.

B. Periodical Publications

30. A periodical publication is a published work in a series, for example, a journal article. A library typically creates a catalog record for a periodical publication when the library receives its first issue. When the institution receives subsequent issues or volumes of the periodical, the issues or volumes are checked in, often using a date stamp, added to the institution's holding records, and made available very soon thereafter, normally within a few days of receipt or at most within a few weeks of receipt.

C. Cataloging / Indexing

31. A researcher may discover material relevant to a topic of interest in a variety of ways. One common means of discovery is to search for relevant information in an index of periodicals and other publications. Having found relevant material, the researcher will then normally obtain it online, look for it in libraries, or purchase it from the publisher, a bookstore, a document delivery service, or other provider.

32. Indexing services use a wide variety of controlled vocabularies to provide subject access and other means of discovering the content of documents. The formats in which these access terms are presented vary from service to service.

33. Online indexing services commonly provide bibliographic information, abstracts, and full-text copies of the indexed publications, along with a list of the documents cited in the indexed publication. These services also often provide lists of publications that cite a given document. A citation of a document is evidence that the document was publicly available and in use by researchers no later than the publication date of the citing document.

34. *ACM Digital Library* – Association for Computing Machinery. The ACM was founded in 1947 and is the world's largest scientific and educational computing society. The portal has two main sections: the ACM Digital Library and the ACM Guide to Computing Literature. The ACM Digital Library provides access

to the journals, newsletters and conference proceedings of the organization. The Guide to Computing Literature is a bibliography of computing literature beginning in the 1950s with more than a million entries. <https://dl.acm.org/>.

35. **CiteSeer^x** – CiteSeer is an evolving scientific literature digital library and search engine that has focused primarily on the literature in computer and information science. CiteSeer was developed in 1997 at the NEC Research Institute, Princeton, New Jersey. The service transitioned to Pennsylvania State University’s College of Information Sciences and Technology in 2003. Since its inception, the original CiteSeer grew to index over 750,000 documents and served over 1.5 million requests daily. <http://csxstatic.ist.psu.edu/home>.

36. **Google Scholar** – This web search engine indexes full text or metadata of scholarly literature, covering numerous formats and disciplines. The size of the database is not published by Google, but researchers have estimated that it contained approximately 160 million items in 2014. (See Oduna-Malea, Enrique; Ayllon, Juan Manuel; Martin-Martin, Alberto; Delgado Lopez-Cozar, Emilio “About the size of Google Scholar: playing the numbers,” Sep 2015. *Scientometrics*, 104(3), pp 931-949, <https://arxiv.org/ftp/arxiv/papers/1407/1407.6239.pdf>).

37. **IEEE Xplore** – The Institute of Electrical and Electronics Engineers is the world’s largest organization for the advancement of technology with some 430,000 members in 160 countries. Known by its acronym IEEE, it has created a

database, IEEE Xplore, that provides access to its hundreds of publications and those of its publishing partners. This includes the content of over 170 journals, more than 1,400 conference proceedings, some 5,100 technical standards, 2,000 eBooks and 400 educational courses. In all, more than 3 million documents, dating from 1872 on, are searchable and available for purchase either through subscription or individually. Many of these records are accessible via Google Scholar. <https://ieeexplore.ieee.org/Xplore/home.jsp>.

38. **ResearchGate** – ResearchGate is the professional network for scientists and researchers. Over 15 million members from all over the world use it to share, discover, and discuss research. <https://www.researchgate.net/about>.

39. **Science Direct** – Science Direct is a website which provides subscription-based access to a large database of scientific and medical research. It hosts over 12 million pieces of content from 3,500 academic journals and 34,000 e-books. The journals are grouped into four main sections: Physical Sciences and Engineering, Life Sciences, Health Sciences, and Social Sciences and Humanities. Article abstracts are freely available, but access to their full texts (in PDF and, for newer publications, also HTML) generally requires a subscription or pay-per-view purchase. <https://www.elsevier.com/solutions/sciencedirect>.

40. **SPIE Digital Library** – The *SPIE Digital Library* is the database of the International Society for Optical Engineering (originally the Society of Photographic

Instrumentation Engineers). The newsletters, journals and conference proceedings of the organization are included in the database. More than 400,000 articles make up the database with 18,000 new research papers added each year. <https://www.spiedigitallibrary.org>.

41. ***Springer Link*** – *Springer Link* provides researchers with access to millions of scientific documents from journals, books, series, protocols, reference works and proceedings. <https://link.springer.com/>.

42. ***Wisconsin TechSearch (WTS)*** – WTS is a set of services offered by the University of Wisconsin Libraries. WTS offers an array of article delivery and research services to any individual or organization who requests the specialized skills of WTS staff in locating and retrieving information, regardless of whether the individual is affiliated with the University of Wisconsin. <https://wts.wisc.edu/>.

V. OPINIONS REGARDING AUTHENTICITY AND PUBLIC ACCESSIBILITY OF REFERENCES

A. Exhibit 1009: Claudio Pinhanez, et al., “Applications of Steerable Projector-Camera Systems.” *Proceedings of the IEEE International Workshop on Projector-Camera Systems at ICCV. Nice, France. October 12, 2003. (“Pinhanez”)*

43. I have been asked to opine on the authenticity and public accessibility of a paper authored by Claudio Pinhanez, et al., “Applications of Steerable Projector-Camera Systems” from the Proceedings of *the IEEE International Workshop on Projector-Camera Systems at International Conference on Computer Vision (ICCV)*

held in Nice, France on October 12, 2003 (“Pinhanez”). The Proceedings were published by the ICCV 2003 committee in a CD-ROM distributed to all ICCV’03 conference, associated workshops, and courses participants⁸ and online at this URL: <http://lear.inrialpes.fr/people/triggs/events/iccv03/cdrom/index.php.html>.

1. Authentication

44. I have evaluated Pinhanez in three ways: (1) by assessing Exhibit 1009, provided to me by counsel; (2) by accessing and reviewing a download of Pinhanez that I obtained from the open access digital repository *CiteSeer* on April 25, 2023, appended to this declaration as Appendix A-1; and (3) by retrieving and reviewing articles that cite Pinhanez, published prior to June 1, 2005, discussed further below.

45. Exhibit 1009 is a copy of Pinhanez provided to me by counsel. I have been informed that it was downloaded from the ICCV 2003 website at this URL: http://lear.inrialpes.fr/people/triggs/events/iccv03/cdrom/procams03/pinhanez_kjeldsen_levas_pingali_podlaseck_sukaviriya.pdf.

⁸ See Information for Authors, ICCV’03, <http://lear.inrialpes.fr/people/triggs/events/iccv03/author-info.php> (last visited May 25, 2023) (“We will also be producing a scratch CD-ROM containing all of the ICCV main conference papers, many of the workshop papers and course notes, and other supplementary materials. The CD-ROM will be distributed to all ICCV main conference, workshop and course participants, and most of it will also be made available on the web.”)

46. Appendix A-1 is a copy of Pinhanez that I downloaded from *CiteSeer*, a respected database stewarded by Penn State University, College of Information Science and Technology, on April 25, 2023, at this URL: <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=6e4804c182b0ed9e2204b5e229efaea0ba96f2a8>.

47. In order to verify that Pinhanez was indeed an article by Claudio Pinhanez, I located his *Google Scholar* record. Pinhanez's *Google Scholar* record is attached as Appendix A-2 and can be accessed digitally at: <https://scholar.google.com/citations?user=YPq3ax4AAAAJ&hl=en>.

48. Pinhanez is listed in Pinhanez's Google Scholar record as shown below and on the third page of Appendix A-2:

Applications of steerable projector-camera systems 41 2003
C Pinhanez, R Kjeldsen, A Levas, G Pingali, M Podlaseck, N Sukaviriya
Proceedings of the IEEE International Workshop on Projector-Camera Systems ...

49. I have compared Exhibit 1009, provided by counsel, to Appendix A-1, the digital version I retrieved from *CiteSeer*. I have concluded that they are the same, which supports my opinion that both Exhibit 1009 and Appendix A-1 are authentic, true, and correct copies of Pinhanez.

50. Additionally, based on my review of Appendix A-2, Pinhanez's *Google Scholar* record, I have no reason to question that this is an authentic document

presented by Pinhanez at the *IEEE International Workshop on Projector-Camera Systems at ICCV* in Nice, France, on October 12, 2003.

51. My finding of authenticity is further supported based on finding Pinhanez in digital format on *CiteSeer* which is where a publication such as Pinhanez is likely to be archived and accessible.

52. Therefore, for the reasons I have described above, I conclude that Exhibit 1009 contains an authentic, true, and correct copy of Pinhanez.

2. Public Accessibility

53. To determine the public accessibility of Pinhanez, I researched articles that cite Pinhanez prior to June 1, 2005. Appendix A-3 is a true and correct screen capture of the Google Scholar entries that cite Pinhanez from 2003 – 2005. The screen capture, which I conducted on May 15, 2023, can be accessed here: https://scholar.google.com/scholar?hl=en&as_sdt=5%2C47&scioldt=0%2C47&cites=2989178860379338159&scipsc=&as_ylo=2003&as_yhi=2005.

54. Appendix A-3 shows nine citations to Pinhanez from 2003 – 2005. Two citations demonstrate the public accessibility of Pinhanez prior to June 1, 2005.

55. Appendix A-4 is an article by Andreas Butz, Michael Schneider, and Mira Spassova, titled: “Searchlight - A Lightweight Search Function for Pervasive Environments” published in *Pervasive*, in volume 3001, April 2004, on pages 351-356 (“Butz”). Butz is listed as citing Pinhanez in Appendix A-3.

56. I downloaded Butz on April 24, 2023 through the Purdue University Libraries at the following URL: https://link-springer-com.ezproxy.lib.purdue.edu/chapter/10.1007/978-3-540-24646-6_26. Butz may be downloaded for a fee at this link: https://link.springer.com/chapter/10.1007/978-3-540-24646-6_26.

57. Appendix A-4, which is a true and correct copy of Butz, lists Pinhanez as a reference, as shown below:

4. C. Pinhanez, R. Kjeldsen, A. Levas, G. Pingali, M. Podlaseck, and N. Sukaviriya. Applications of steerable projector-camera systems. In *Proceedings of the IEEE International Workshop on Projector-Camera Systems at ICCV 2003*, Nice Acropolis, Nice, France, October 12 2003. IEEE Computer Society Press.

58. Based on this, I conclude that Butz is evidence that Pinhanez was known and accepted as a scholarly reference when Butz was published in *Pervasive* in its April 2004 issue, which is prior to June 1, 2005.

59. Appendix A-5 is an article published in Japanese that appears on Appendix A-3. The citation in English is: Tovohisa Nakada, Hideaki Kanai, and Susuu Kunifuji, “A Supporting System for Finding Lost Objects by Spotlight”, IPSJ SIG Technical Report 2005/3/17, pages 25-30 by Information Processing Society of Japan, March 17, 2005 (“Nakada”).

60. I retrieved Nakada, appended as Appendix A-5, on May 15, 2023 from the following open access URL:

https://ipsj.ixsq.nii.ac.jp/ej/?action=repository_uri&item_id=42046&file_id=1&file_no=1.

61. Appendix A-5 is a true and correct copy of Nakada. Page 30 of Nakada includes Pinhanez in its list of references as shown below:

[7] C. Pinhanez, R. Kjeldsen, A. Levas, G. Pingali, M. Podlaseck, N. Sukaviriya, "Applications of steerable projector-camera systems", IEEE International Workshop on Projector-Camera Systems at ICCV 2003, 2003

62. Nakada's citation to Pinhanez provides further evidence that Pinhanez was known and accepted as a scholarly reference when Nakada was published as a Technical Report by the Information Processing Society of Japan on March 17, 2005.

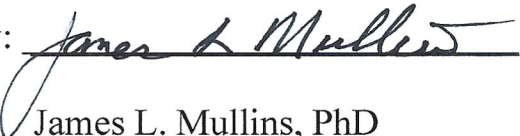
63. Based on the above, I conclude that Pinhanez, submitted in this proceeding as Exhibit 1009, is an authentic document that was publicly accessible before June 1, 2005.

VI. RIGHT TO SUPPLEMENT

64. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner or its expert(s) or counsel may raise, and to take into account new information as it becomes available to me.

65. I declare under penalty of perjury that the foregoing is true and correct.

Executed on October 20, 2023

By: 
James L. Mullins, PhD

Appendix A-1

Applications of Steerable Projector-Camera Systems

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Abstract

How can interactive computer interfaces be created anywhere in a space without wiring or modifying objects or people? We propose using steerable projector-camera systems employing computer vision to realize such "steerable interfaces." In this paper, we illustrate the potential of the new kinds of applications enabled by steerable interfaces and discuss the challenges imposed on computer vision through the presentation of four application prototypes: a collaborative assembly task coordinator; a multi-surface presentation viewer; a ubiquitous product finder for retail environments; and an interactive merchandise shelf.

1. Introduction

The main goal of our research is to create devices capable of realizing the *ubiquitous computing (ubicomp)* vision of everywhere computer access and seamless integration of computers with the real world [1]. However, unlike the most commonly proposed devices that have to be either worn or carried by the user (such as cell phones or PDAs), or embedded in the environment, we are investigating devices that can create interactive displays with minimal physical change to the user or to the environment.

In this context, using projectors to create interfaces becomes a natural candidate, especially when combined with cameras and computer vision systems able to directly detect user interaction with the projected surface. The combination projector-camera is thus able to create *projected interfaces* on most planar surfaces without requiring any modification on it.

However, if the goal is to provide multiple points of seamless computer access in an environment, it is not practical to install pairs of projector-cameras facing every possible surface. Even in the unlikely case that projectors become extremely cheap, installation of these devices will still be costly. Even worse, any change in the configuration of the environment will require re-installation and re-wiring of many devices.

To cope with those problems, we have been advocating the use of *steerable projected interfaces* [2, 3], referred in this paper simply as *steerable interfaces*. Steerable interfaces can be created, for example, by fitting a pan/tilt

mirror into a LCD projector and combining it with a pan/tilt/zoom camera.

We have described the basic structure of the vision systems used in our prototypes in previous publications [4, 5]. In this paper we focus on four different application prototypes that explore the potential of steerable interfaces. These applications employ vision systems that detect point-and-click interaction, toolbar scrolling, and simple user activity recognition. However, unlike traditional vision-based interfaces, these vision systems are required to work seamlessly on distinct surfaces under very different observation angles and lighting conditions. They also have to cope with the changes in the pattern of user interaction caused by moving the interface to a new surface, which alters the relative size and orientation of the gesture to the interface. In some ways, these applications require computer vision systems much more robust and adaptable to contextual changes than currently used vision systems.

This paper presents these new computer vision-based applications that are only possible due to use of steerable projectors and cameras. As we present these applications, we analyze and discuss the challenges created by steerable interfaces to computer vision and the ways we have addressed them. We conclude by suggesting possible ways to improve the performance of steerable vision systems.

2. Related Work

Deviceless interaction with projected images based on video processing was pioneered in the 1980s by Krueger [6] in systems that often used a backlit white background to simplify segmentation. Real-time static background segmentation became a reality in the 1990s, notably in the ALIVE system [7] and the technique has been a cornerstone of most segmentation work in vision-based gesture recognition.

However, only a little of that work has attended to the problems of segmentation in the context of a projected display. Because the projected image drastically changes the appearance of the hand, we tend to agree with Hardenberg and Berard [8] in that background subtraction does not give reliable results in the presence of strong projected images.

Different proposals have been made to use hand or body gestures to interact with the projected images. In

general, gesture-based interaction methods tend to fall into one of two categories: either variations of a point-and-click paradigm [8, 9] or application-specific pose or motion gestures [10]. Both these approaches have disadvantages. While the point-and-click approach is often not well suited to hand pointing due to limited resolution and the lack of a natural “click”, a large number of application-specific gestures makes interfaces complex: users have to learn and execute these gestures largely without feedback, as discussed in [11].

3. Computer Vision for Steerable Interfaces

The applications described in this paper use a device to create steerable interfaces called the *Everywhere Displays projector (ED-projector)* [2]. Figure 1 shows a prototype of this device, made of off-the-shelf components: a LCD projector, a pan/tilt mirror used in theatrical lighting, and a videoconference pan/tilt/zoom camera.

The system is currently run on two different computers, one responsible for the application software and the projector software; the other controlling the positioning of the camera and runs the computer-vision system responsible for detecting user interaction. The projector software stores and manages the calibration parameters to correct the distortion caused by oblique projection as well as the projector focus and zoom parameters. In the current implementation, these parameters are determined manually as described in [2].

Our methods to detect user activity involve the interpretation of the path of the user’s hand. Because the projection can radically change the appearance of objects moving through it, appearance-based techniques were ruled out. Instead motion is detected by looking at the differences between adjacent images in the video stream. Hands are tracked by looking for fingertips in the filtered motion data. Candidate fingertips are identified based on shape and evaluated using spatial heuristics such as orientation, distance from the user’s body, and the previous fingertip locations.

To build an interface, application designers assemble “widgets” that specify areas where users can interact. Each type of widget responds differently to the user’s motions. A touch widget looks for an in-pause-back motion of the hand. A continuous motion widget reports the relative location of a fingertip in one or two dimensions. The system can also track objects of distinct colours. As we see, our system employs traditional computer vision methods in the implementation of the basic widget set (see [4] for details).

Most real-life vision interface systems incorporate the vision system as a module that is hard-coded to operate under a fixed set of circumstances. Our system, on the other hand, requires the application to send the vision system a description of the user interface as a



Figure 1. Prototype of the ED-projector.

configuration of widgets (describing *what* the interface is). Based on these specifications, the vision system assembles a set of image processing components that implement the interface, sharing computational resources when possible. To change the interaction, a new interface description can be sent to the system at any time.

The system, described in detail in [5], also provides for the deployment of an interface onto different real-world planar surfaces. Like Zhang et al. [12], we dynamically map the interactive interface based on the four corners of the contour of the surface. However, in our system the parameters of the surfaces where the interface can be realized are represented and referenced independently of any particular interface. These include the size, location and perspective distortion within the image and characteristics of the physical environment around that surface, such as the user’s likely position while interacting with it. When the application requests an interface to be activated on a particular surface (that is, defines *where* the interaction should happen in the environment), the system retrieves the surface parameters and propagates them through the assembly of image processing components that implements that interface.

By explicitly decoupling the information describing the characteristics of *where* an interface happens in an environment, i.e., surface-specific information, we enable: (1) the porting an application to a new environment where the interaction surfaces could be different; (2) the use of one surface by multiple applications; and (3) the use of the same interface on multiple surfaces.

4. Applications Using Steerable Interfaces

Steerability considerably expand the potential of projected interface systems by making them devices much more adaptable to environmental changes, especially when compared to embedded displays and monitors. For example, if the furniture of an office is rearranged, it is

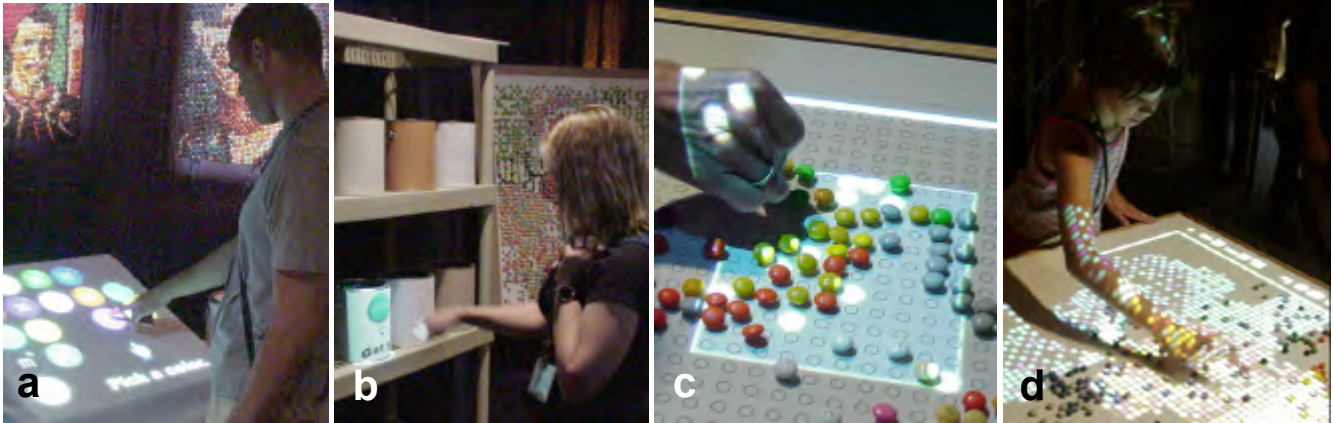


Figure 2. The M&M picture assembly task: a) choosing a color; b) “clicking” a bucket after getting the M&M’s; c) placing the M&M’s on the highlighted areas; and d) “finger painting” to reveal the complete picture.

necessary to rewire monitors and, many times, remove and reinstall embedded displays. Instead, if a steerable interface system is used, adaptation is simply a matter of recalibrating the position and parameters of the interactive surfaces by software.

However, the addition of steerability to a projected interface system goes beyond easy and flexible deployment of interfaces on different surfaces. It also enables a new set of applications that explore more direct connections to real-world objects. In particular, it allows the creation of augmented reality applications where information about objects is projected directly onto or around them, freeing the users from the inconvenience of wearing head displays and cumbersome input devices and avoiding the difficulty of registering the computer generated imagery to the real-world view.

The possibilities opened up by the use of steerable interfaces to create different and exciting applications come with a price. On the display side, there are issues such as reduction of perceived resolution, constraints on environment brightness, and occlusion, as discussed in [2].

4.1. Collaborative Assembly Task Coordinator

Steerable interfaces can augment reality without requiring users to wear goggles or other cumbersome devices. To demonstrate this premise, we developed for a the Emergent Technologies Exhibit of SIGGRAPH’01 a whimsical demonstration of a system that uses steerable interfaces to coordinate a collaborative assembly task. In this prototype application, the object to be assembled is a picture made of 3,000 M&M’s (multi-colored sugar-coated chocolates) where each M&M is regarded as a pixel of the picture. Each user contributes to the task by placing 10 to 15 pixels. Here is a description of the main characteristics of this application:

Context: a collaborative assembly task in a factory.

Application Goal: to guide users to find the components to be assembled and to help placing them in the appropriate position.

Technology: the application uses an ED-projector overlooking the assembly area. The vision system implements widgets that detect touch events and that report continuous motion of the user’s hand on a surface.

Interaction: as the user enters the environment, she is asked to touch a picture projected on a board to activate the system. The system responds by projecting an instruction asking the user to go to the selection area. The interface is then steered towards a table. Figure 2.a shows this table as it is transformed into an interactive menu for color selection. The user simply touches the color of his choice to select it. Then the user receives a projected instruction prompting him to look for a highlighted bucket. In Figure 2.b, the system highlights the bucket that contains the M&M’s of the selected color and provides additional information on how many M&M’s to extract from the bucket. The interface also includes a touchable button, where the user indicates that the retrieval of M&M’s is completed. When this button is touched, the system projects on the bucket an instruction telling the user to walk to the picture board. In Figure 2.c, the system is pointing to the exact places on the picture board where the M&M’s should be placed. After the M&M’s are put in place, the user can signal the end of this task by touching a button projected on the side of the picture board. The user is then invited to wave her hand over the surface to progressively reveal the rest of the picture being built (see also the video, from the system’s camera point of view, at <http://www.research.ibm.com/people/p/pinhanez/download/video1.avi>).

The computer vision system faced many issues in this application. The first difficulty involved the interactive menu for color selection. As shown in Figure 2.a, this menu presented a choice among 18 buttons, arranged in a

Table 1: Performance of the vision system (130 users)

	success	false positives	false negatives
Entrance	88%	9%	3%
select board	94%	2%	4%
buckets	55%	33%	12%
board (place)	91%	8%	2%
board (paint)	80%	2%	18%
total w/o buckets	89%	6%	5%
total	81%	12%	7%

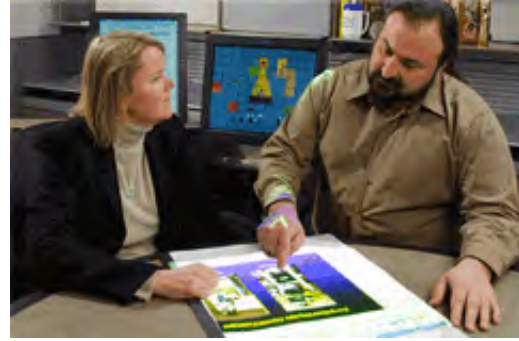
grid configuration closely juxtaposed to each other. Correct selection was possible because the system looked for the complete gesture of touching and not simply by the presence of the hand in a particular spot. Therefore, the user could select a color in the top row without triggering the buttons on the rows below. As we see here, simple tracking without gesture recognition is often insufficient to implement even basic projected interfaces.

A second major challenge for the vision system was to realize the bucket interface dialog onto the many different buckets. At the time of this demonstration, the automatic mapping of configurations of widgets onto surfaces described in section 3 was not implemented, so each interface had to be painstakingly mapped to each surface that realized it. In fact, the difficulties experienced during this demonstration were a major factor to develop the description-based interface system described in section 3..

More than 650 novice users participated in the collaborative assembly task demonstration. Considering that the vision system and the projection system were integrated only weeks preceding the exhibition, the combined system worked remarkably well. As shown in Table 1, a sample with 130 consecutive users with 621 button touch events (touching gestures or false detections) yielded correct detection of touching gestures in 81% of the events, with 12% false negatives and 7% false positives. If the bucket events are excluded from the count, the performance exceeds 89%.

The buckets yielded a high number of errors for several reasons. The biggest problem was that while picking M&M's from the bucket, the user often partially or completely occluded the display with their head or back, accidentally triggering the button projected on the bucket. A possible way to handle this is to include in the vision system improved methods to distinguish between the shapes of hands and other body parts. Currently, the system only looks for fingertip-shaped patterns on the motion image. However, if view-based methods are used to identify body parts larger than a fingertip, the apparent shapes can vary dramatically from surface to surface due to the different relative positioning of camera.

Although we choose to use the M&M's placement task to demonstrate steerable interfaces in augmented reality, it

**Figure 3. Anywhere presentation viewer.**

should be evident the applicability of this technology in real-world assembly tasks and similar augmented reality scenarios.

4.2. Anywhere Presentation Viewer

Another important area of applications of steerable interfaces involves the access to desktop applications from different surfaces. A typical scenario occurs when people assemble in an office or meeting room to review electronic documents. According to the number of participants and their roles, documents are preferably viewed by individuals on monitor-like displays, by large groups of people on vertical screens, or by a small number of people in configurations that better facilitate collaborative work such as the one shown in Figure 3.

Trying to address these problems, we developed a presentation viewer that can move to different surfaces:

Context: office or meeting room.

Application Goal: to create a viewer for presentations that can be accessed on walls or tables to facilitate collaborative work.

Technology: an ED-projector overlooks the working area. The vision system utilizes only touch widgets; the interfaces are dynamically defined by the application and mapped automatically onto the calibrated surfaces.

Interaction: using a touch-screen LCD monitor, the user selects through an icon a surface in the environment to launch the application. The presentation is projected on the selected surface, topped by buttons allowing the users to select the next, the previous, or the first slides, or to dismiss the viewer. The viewer can be moved to other surface by selecting the corresponding icon on the LCD monitor.

This application clearly demonstrates the need of a vision system that can automatically map any application interface onto any given surface. In real offices and meeting rooms, tables move to different areas, walls are set up and removed, etc. Easily coping with these environmental changes is an essential feature of the vision system here.

A difficulty with this application, particularly in collaborative scenarios such as the one depicted in Figure 3, is that the context invites multi-user interaction. If that is the case, buttons have to respond to activation patterns from different directions corresponding to where each user is positioned relative to the interface. Such ability is not currently supported by our system: it assumes that all touch widgets in an interface are accessed from the same direction. Supporting multi-directional access requires either tracking and differentiating multiple fingertip paths simultaneously, which is currently very error prone, or monitoring the location of every user. In the second case, the vision system may use contextual information provided by an environmental user positioning tracking system. We are also evaluating more sophisticated hand path representation and recognition methods.

4.3. Ubiquitous Product Finder

Computerized access to information in public spaces such as malls and stores has been primarily deployed through kiosks. A major advantage of using virtual display systems such as the ED-projector in such spaces is that they can be installed on the ceiling, thereby preventing accidental damage and discouraging vandalism and theft.

We are exploring such ubicomp applications in public spaces in the context of retail environments. The first application developed in this framework is a system to help customers to find products in a large store. A major requirement for this application is ubiquity, i.e., the product finder has to be easily accessible from anywhere in the store. Another requirement is that it has to be simple to learn and use.

Figure 5 shows a conceptual view of the *ubiquitous product finder*. ED-projectors are installed in every aisle, and small white boards placed in strategic locations on the shelves. These boards can be easily moved to different positions to respond to marketing and customer needs. A large table is placed at the entrance to the store (on the right side of Figure 4). On it, an enlarged, intuitive-to-use version of the interface is projected aiming to make customers acquainted to the system. Signage boards are hung up from the ceiling or placed on top of the shelves, allowing the system to project directions to the product requested by the customer or to display advertisements when the system is idle.

A full-scale version of this application has not been deployed yet. Here, we describe a laboratory prototype of the system we have built and tested.

Context: a large retail environment.

Application Goal: to help customers everywhere in the store to find products by pointing directly to where they are located.

Technology: (laboratory prototype) an ED-projector is mounted on the ceiling. A table with a wooden red slider

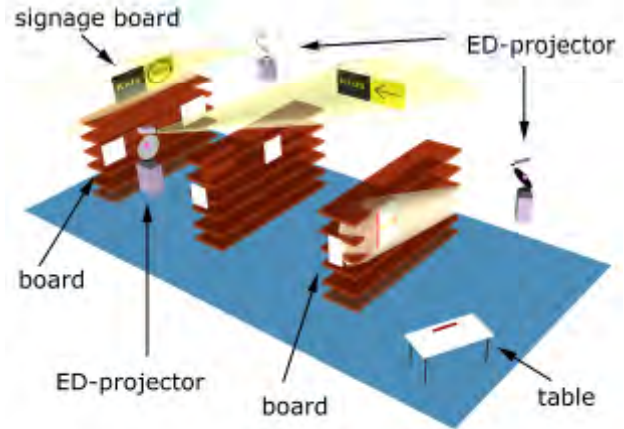


Figure 5 Concept of ubiquitous product finder.

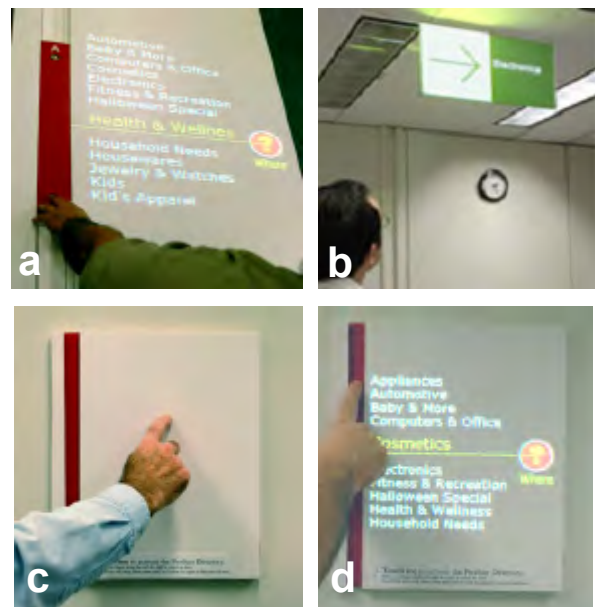


Figure 4. Prototype of ubiquitous product finder.

is used for projecting a larger introductory version of the product finder interface. Two smaller foam boards, visually similar to the table with the slider, are placed on the walls representing the smaller replicas of the same interface used in other areas of the store. The vision system is able to detect touch events, hand position and movement over the foam boards, and the position of the wooden slider relative to the table.

Interaction: the product list is projected on the product finder table located at the entrance of the store. The user can move the wooden red slider on the left of the table to find a product as illustrated in Figure 4.a. As he does this, the product list projected to the right of the slider scrolls up and down mirroring the motion of the slider. Once the user touches the “where” symbol on the right, arrows guiding the user to the location of the highlighted product are projected on signage boards hanging from the ceiling

as illustrated in Figure 4.b (see also video at <http://www.research.ibm.com/people/p/pinhanez/download/video2.avi>). Alternatively, the user may initiate the product finder from the foam boards at other locations of the store by touching the boards as shown in Figure 4.c. This action triggers the system to project the product finder interface onto these foam boards as shown in Figure 4.d. In the wall version, the user slides his finger up and down a red velvet strip to scroll the product list (see <http://www.research.ibm.com/people/p/pinhanez/download/video3.avi>).

Our laboratory prototype of this application currently does not address two important issues present in real stores. First, we use a camera-based user tracking system (based on [13]) to detect proximity to the foam boards. If a user is close to one of them, we aim the ED-projector camera to the board surface and, without projecting any information, wait for the user to “call” the system by touching the board. This is not a practical solution in real store where multiple customers may be close to different foam boards at the same time. We envision here the use of an array of steerable cameras that can be dedicated exclusively to monitor the foam boards. The second issue is the inability of the system to help more than one customer at a time. In particular, if many boards share an ED-projector, we may have situations where users will have to wait for their turn to use the product finder. The severity of this is yet to be tested in a real-world deployment, but we expect that customers may tolerate reasonable waiting times as the situation is similar to when they consult an information desk or a sales assistant.

The flexible structure of our computer vision system simplified significantly the implementation of the laboratory prototype. To detect the movements of the wooden slider of Figure 4.a, a widget to detect linear movements of blocks of solid color was implemented. In the case of the foam boards, fingertip tracking is used to determine its position on the velvet strip as shown in Figure 4.d. Switching between the two different widgets is accomplished by the application simply sending the vision system the description of the appropriate interface.

We initially had some difficulties with the interaction on the velvet strip. After scrolling through the list and finding the desired product, users move away to touch the “where” button on the right, sometimes causing unwanted scrolling before they exit the tracking region. We solved the problem heuristically, ignoring quick motions after a pause that immediately exit the tracking region

This problem is common to many gesture-based interfaces: the segmentation of continuous gestures into distinct “phrases”. In our case the problem is simplified somewhat by using the spatial adjacency of gestures to interaction widgets. As with the problem of continuous speech, there is some amount of “co-articulation” that

affects the ends of adjacent phrases, complicating their recognition. Gestural phrasing has been an issue for many years but, despite many different proposals (such as [14]), it is still largely unsolved.

4.4. Interactive Clothing Bins

Another application developed in the context of a retail environment uses a checkerboard arrangement of bins containing women’s pants and projectable surfaces as shown in Figure 6. It explores steerable interfaces as a way to augment the functionality of everyday objects and furniture. In this particular application, the system detects user interest with the product in a particular bin and automatically brings information designed to assist the customer.

Context: a retail environment.

Application Goal: to assist customers interested in a product by displaying information about it.

Technology: an ED-projector is aimed at the clothing bins. In our particular implementation, the system is unable to project an image large enough to cover all projectable surfaces on the bins. Instead, it selects groups of juxtaposed surfaces and steers the interface towards them according to the user hand’s position, i.e., the top parts of the bins, the bottom part of the bins, etc. The vision system can detect user activity in each of the clothing bins and touch events. No surface contains any sensor or wire. A camera-based user tracking system (similar to [13]) is used to determine the position of the user relative to the clothing bins.

Interaction: When the user is at a distance from the bins, a circulating series of advertisements for women’s clothing are projected on the panels, trying to attract customers to the area. When the user approaches the bins, the display is changed to advertise the store’s credit card and special promotions. Once the user starts examining pants in a bin, information pertaining to the pants in that bin is displayed in the proximity of the bin. Additional interactive panels are projected allowing the user to find information about similar pants styles, to check the size chart, or to check whether the desired size and color is available in stock (see demonstration video at <http://www.research.ibm.com/people/p/pinhanez/download/video4.avi>).

The major difference between this application and the ones previously examined is that this system proactively tries to engage and help the customer. By recognizing user activity in a particular bin (by simple hand tracking) and interpreting it as an interest in the products stocked there, the application takes the “liberty” of augmenting the environment with information. This example clearly demonstrates the potential of steerable interface systems to create new models of interaction by directly engaging

people while they execute everyday activities in the real world. Since application interfaces can be created on areas very close to where the activities are happening, user attention can be more easily grabbed. This kind of engaging application involving physical objects cannot be easily implemented with traditional embedded displays such as monitors or kiosks.

This example also shows how computer vision methods and algorithms for recognition of human activity and behavior can be used for the development of applications with steerable interfaces. Our system determines user interest in a particular bin by detecting long duration hand movements within the bin. The performance achieved with this simple measurement is adequate for a research prototype but we clearly see opportunity here for more sophisticated methods of action and behavior recognition.

5. Improving the Performance of the Vision System of a Steerable Interface

By decoupling the functional definition of the interface from the specification of its location in the physical environment and in the camera image, the ED-projector vision system supports a great deal more flexibility than most vision-based interaction systems. This flexibility requires significant architectural complexity to dynamically realize an efficient recognition process from the task and surface descriptions.

Up to this point, our efforts have mostly concentrated on developing this flexible internal architecture [5], while the interaction widgets themselves have been comparatively simple. We are now beginning to concentrate on developing widgets that are capable of supporting more interesting interactions. This work is proceeding along several dimensions.

People have difficulty seeing the exact shape of a moving object, so natural gestures most often consist of a sequence of motions and static poses, where a hand movement is followed by a static pose, possibly followed by another movement, and so on [9]. In order to recognize hand poses, it will be necessary to either incorporate techniques to recognize shape in the sparse and noisy motion data or to incorporate hand segmentation techniques that do not rely on motion. However, as mentioned above, to avoid problems caused by the change in appearance of the user's hands as they pass through the projected image, the current interactions have all been based on detection and analysis of motion in the video stream. One possible alternative is to use a segmentation method that uses knowledge about the image being projected, the physical surface where the interface is being projected on, and how they interact, so that it can estimate the appearance of the projection to the camera. By using techniques such as those presented in [15], it may be



Figure 6. Interactive clothing bins.

possible to estimate the appearance of the projection in the digitized video stream. This will also allow interactions to take place in the presence of a changing projection, such as a projected video clip.

Interestingly, the flexibility provided by computer vision allows interactions that are more abstract than the manipulative hand gestures implemented to date. One line of investigation concerns intentional control actions that the user takes with parts of the body other than their hands. These include interactions where whole body movements such as waves or jumps are used to control the interaction [16].

In addition to extending the gesture recognition capabilities of the system, we feel performance can be significantly improved by enabling the system to adapt to its current context. There are several areas where adaptation may be important. For instance, the current widget set requires information about the expected size and orientation of the user's hand. By making better use of user tracking information and observing user movements as they approach a widget, it is possible to determine this type of information automatically.

Every person moves with different rhythms and patterns. When users interact with a system using physical devices like a keyboard or mouse, the device standardizes and masks many of these differences, but because our vision system directly senses and interprets a user's movements, it can be sensitive to them. Techniques similar to [17] can allow adaptation to an individual user's movement patterns.

One constraint on any interaction system is that it be able to respond to the user smoothly and in a timely manner. For a vision-based system this implies it runs at a sufficiently high frame rate. Research with other interaction methods [18] has shown that tracking rates on the order of 10 Hz and response times less than 200ms are needed for a system to feel comfortable, except in the case of manipulation of virtual objects. If the frame rate falls below what is required to support these response times there are several trade-offs that can be adjusted to

compensate. For example the incoming resolution may be reduced, trading off accuracy for speed. We are exploring techniques to do this automatically.

6. Conclusion

We have shown in this paper how possible ways to use computer vision in applications based on steerable projected interfaces. Our basic approach involves using motion data to identify the user's hand and path analysis to identify touch events, hand movement, and simple manipulative actions.

A major factor enabling the development of three of the prototype systems was the application-driven dynamic definition of interfaces and their automatic mapping to any surface known by the vision system. With this architecture (defined in detail in [5]), surface and viewpoint-specific characteristics are abstracted from the development process of the application.

Some shortcomings of the current system and challenges for computer vision have also been identified as a result of our work developing these applications. In general, projected interfaces limit the use of appearance-based techniques. Also, steerability requires gesture recognition algorithms to be viewpoint independent or, at least, adaptable to new viewpoints if basic contextual information is provided. Gesture segmentation based on spatial location and greater use of contextual information such as user position contributed to the success of the system. As the complexity of the underlying widgets increases, a challenge will be to ensure that the additional complexity does not spill over to affect the application developer or the end user.

Finally, in this paper we demonstrate that ubicomp applications can be implemented based on the steerable interface paradigm. The extension that this paradigm will become a major part of the ubiquitous computing reality substantially depends, in our view, on the development of adequate and robust computer vision systems that satisfy the constraints imposed by projection and steerability.

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Appendix A-2



Claudio Pinhanez

IBM Research - Brazil / C4AI - Univ. of São Paulo

Artificial Intelligence
 Conversational Systems
 HCI
 Ubiquitous Computing

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[A Butz](#), [M Schneider](#), [M Spassova](#) - *Pervasive*, 2004 - Springer

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[R Handorean](#), [C Gill](#), [GC Roman](#) - ... 2004, Linz/Vienna, Austria, April 21-23 ..., 2004 - Springer

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[S Gupta](#), [C Jaynes](#) - ... *Vision and Pattern Recognition (CVPR'05)* ..., 2005 - [ieeexplore.ieee.org](#)

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論文抄録 隠れていても頻りに移動する物でも, その物にスポットライトをあてるシステムを構築した. そのアプリケーションとして「部屋の中での紛失物探し」と「本棚での関連本探し」...

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[PDF] UbiComp: Becoming Superhuman

[J Scott](#) - *Proceedings of the UbiComp 2005 Workshop on* ..., 2005 - [microsoft.com](#)

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An intelligent disassembly assistant for man-machine demanufacturing

[MB Kuren](#), [J Soltani](#) - *Proceedings, 2005 IEEE/ASME* ..., 2005 - [ieeexplore.ieee.org](#)

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SearchLight – A Lightweight Search Function for Pervasive Environments

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Abstract. We present a lightweight search function for physical objects in instrumented environments. Objects are tagged with optical markers which are scanned by a steerable camera and projector unit on the ceiling. The same projector can then highlight the objects when given the corresponding marker ID. The process is very robust regarding calibration, and no 3D model of the environment is needed. We discuss the scenario of finding books in a library or office environment and several extensions currently under development.

1 Introduction

Ubiquitous computing landscapes extend our physical surroundings by a computational layer providing new functionalities. One such functionality can be the capability of objects to make themselves known in order to be noticed or found by humans. This functionality was already proposed in the original Ubiquitous Computing vision [8]. A search function for physical environments would alleviate the need to keep track of all of the things in our environment.

One obvious application is keeping track of books in our office, in a library or a book store. Let's think of a library with ubiquitous display capabilities. Let's assume there will still be a conventional inquiry terminal to find out about books. The inquiry interface on the computer terminal in a library could then just provide an additional "show this book" button for the selected book, which prompts the environment to highlight its position on the shelf.

Let's think of an instrumented office in which there are many books and other things, either neatly sitting on the shelf where they belong, or left somewhere in the room on a pile. A physical search functionality will find and highlight missing objects for us, no matter where we left them. In this paper we describe such a search function for physical objects, and how it was implemented in our instrumented environment.

2 The SUPIE Environment

The Saarland University Pervasive Instrumented Environment (SUPIE) is an instrumented room with various types of displays, sensors, cameras, and other

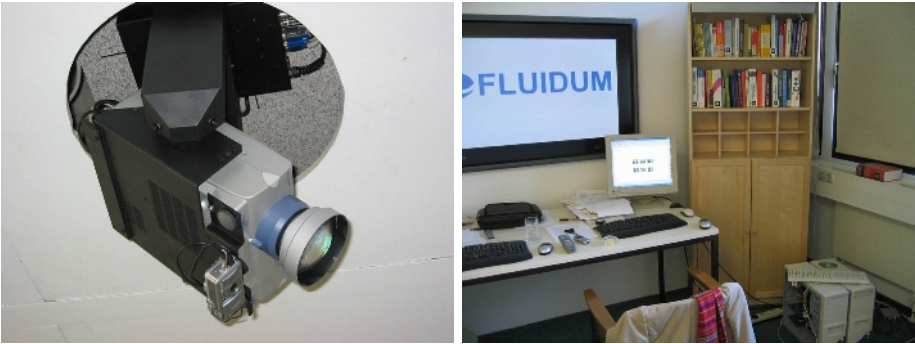


Fig. 1. The steerable projector mounted on the ceiling (left) and one corner of SUPIE with a book shelf (right)

devices. By means of a steerable projector, the room has continuous display capabilities which are limited in resolution and temporal availability (only one area at a time). The various other displays provide islands of higher resolution and interactivity within this display continuum.



Fig. 2. Images taken during the scanning process (left) and an example of an AR Toolkit marker (right)

The projector can project arbitrary light patterns onto all surfaces in the room with line of sight to its position in the center of the ceiling. An attached camera can take high resolution pictures from (almost) the same position and scan them for objects and markers. It also provides a low resolution video stream in real time for the recognition of movements.

3 Implementation of *SearchLight*

3.1 General Thoughts

All that is needed to implement *SearchLight* is the steerable projector with its camera and the capability to recognize optical markers. The only determining factors for finding objects and highlighting them, are the pan and tilt angles of the unit moving the projector. If a marker is found at given pan and tilt angles, these can be stored and used directly for projecting a highlight area around the corresponding object. Thus, not even a 3D model of the room is needed. Absolute registration errors of the camera and projector will cancel each other out since they are mounted in one unit and moved together.

3.2 Devices

The steerable projector is mounted on a moving yoke produced by a stage equipment manufacturer, controlled via a DMX interface, and mounted in the center of the ceiling of the room. The unit carries a 3.000 ANSI lumen projector with a lens of long focal length, in order to provide sufficient contrast and brightness in daylight. The camera attached to the projector (see figure 1 right) is a regular Digicam with an image resolution of four Megapixels. The high resolution pictures are triggered and read out over USB with the camera's freely available SDK. Each object that should be found by *SearchLight* is tagged by an AR Toolkit marker (see [1]). Each marker has a large black fringe and an individual small black symbol on a white background. (See figure 2) These markers are recognized by the Java version of AR Toolkit, the *JAR Toolkit*.

3.3 Implementation

SearchLight performs two main tasks: It *scans* the room for markers and memorizes the corresponding angles, which are used later to *show* searched objects.

Scan. The room is scanned by taking slightly overlapping pictures in all horizontal and vertical directions (see Fig. 2 left). Each picture is analyzed using JAR Toolkit. Marker IDs are stored in a list together with their pan and tilt angle, derived from their position and orientation in the picture and the orientation of the moving yoke when taking the picture.

Show. After the room has been scanned, the user can search for marked objects. The request to show a specific book in a library can, for example, be given from the library enquiry system through a "show this book" button. The object's Marker ID is then looked up and the projector unit moves to the position where this marker was detected during the last scan and projects a bright spot around the searched object. Due to the speed of the steerable projector, highlighting an arbitrary object takes less than a second, thus providing almost instant feedback to the search request.

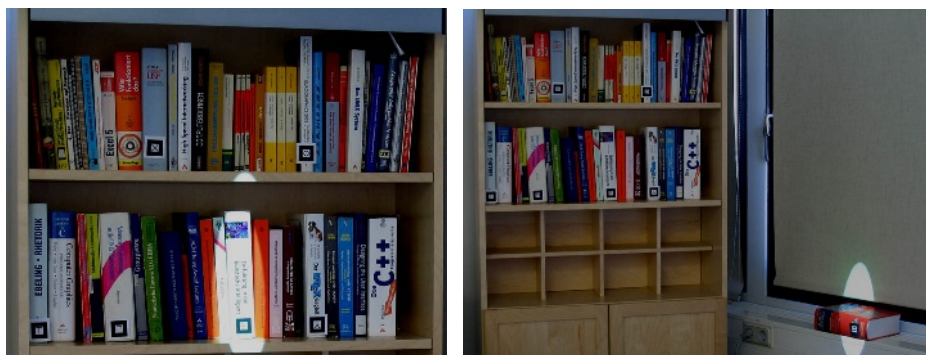


Fig. 3. A book was found on the shelf (left) and another one on the window sill (right)

4 Related Work

The use of a steerable projector to transform environments into continuous displays has first been proposed by Claudio Pinhanez [3] at IBM. In their Siggraph 2001 emerging technologies demo, where colored M&Ms were composed by visitors to form large pixel images, the Everywhere Display Projector was used to highlight trays with different colors on a shelf. The positions of these trays were, however, not acquired automatically.

Additional applications are presented in [4], including a ubiquitous product finder and an interactive shelf. The product finder guides people towards products in a store environment, using blank projection surfaces as individual direction signs and interaction spaces. The interactive shelf uses similar surfaces for the display of product-related information. While these prototypes are strongly related to the work presented here, both of them require dedicated projection space in the environment.

Raskar et al. present in [5] a method for simultaneous acquisition of room geometry and use of the acquired surfaces as an output medium for mobile projectors. They also use markers for object recognition and annotation. The FindIT Flashlight [2] can find objects instrumented with responsive electronic tags. Users scan the environment with an electronic flashlight emitting a digital code, and the corresponding tags respond when hit by the flashlight's beam. Both systems rely on the user pointing to the right direction, while in our demo, the environment actively controls the projector.

In [7] another augmented library environment is described, where books or their requested positions can be highlighted on the shelf through a head-mounted display. While this approach is more general in terms of scalability and topology of the environment, it requires an instrumentation of the user and an explicit 3D model of the environment, which we were able to avoid.

5 Current Results and Future Work

One immediate application scenario is a public library where each book has a marker on its front and back side and on the spine. In this way a book can be located even if it is not at its usual place in the shelf. When the library is closed, *Search Light* can scan all shelves and tables and take inventory. During opening hours, only certain areas must be re-scanned as described above. With our experimental setup in SUPIE (room size 5x6m, shelf on the wall, 4 Megapixel steerable camera with 3x optical zoom in the center of the ceiling) we were able to reliably recognize markers down to a size of 10mm in the whole room. Initial scanning of the room took roughly 1 hour, mostly due to the slow transmission of pictures over the USB 1.1 link to the camera. Currently we are improving *SearchLight* in various respects.

5.1 Continuous Model Update

In the current demo, scanning is done only once when *SearchLight* is started. In the future we will use idle times of the projector to systematically re-scan the room for changes. This process will also prioritize regions where changes are more likely by using additional sensors, such as RFID tags or motion detection with other cameras. On the down side, including external sensors will require the use of at least a simple 3D model of the room in order to relate locations of sensor events to pan and tilt angles of the projector. This model might, however, be acquired automatically by methods similar to those described in [6]. Upcoming versions of *SearchLight* may use the camera even when the projector is used for other tasks by just analyzing images as they appear rather than actively steering the camera to certain positions for scanning.

5.2 Extension to Other Markers

In theory, existing bar codes on many products could be used for the recognition process. In the case of books, OCR could even eliminate the need for markers altogether, since book spines and covers are designed to clearly identify books. Currently, we are working on integrating RFID tags by watching the region around the RFID antenna. When the antenna registers a change in its field, a new image is taken and the exact position of the new resp. removed object is identified from a difference image. As a side effect the exact silhouette of the object might be obtained for highlighting by the projector. To overcome the visibility problems inherent to the use of optical markers, radio tags might even fully replace them. This will, on the other hand, make a 3D model of the environment necessary, in order to relate object positions to pan and tilt angles of the projector.

5.3 Fuzzy Search Results

If the exact position or dimension of a searched object is unknown, a fuzzy search result can be visualized as a spot whose diameter reflects the amount of

uncertainty. If, in addition, we know the probabilistic distribution over possible locations, we can adjust the brightness of the spot to reflect this distribution. In the extreme case this means highlighting a whole area of the room, which would signify that the object must be "somewhere in that area".

6 Conclusions

We have discussed an approach to implementing a search functionality for physical environments by a steerable camera-projector unit, and we have shown that it is possible to implement this functionality without an explicit 3D model of the environment. One big advantage of our approach is, that no calibration between the projector-camera-unit and the environment is needed. One obvious limitation is that only objects within sight from the unit can be searched and found. This limits the topology of the environments in which our approach can be used.

Acknowledgements. The work described here was funded by "Deutsche Forschungsgemeinschaft" under a young investigator award for the project FLUIDUM. The SUPIE environment is shared with the REAL project. We thank our anonymous reviewers for helpful suggestions and pointers to additional related work.

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Appendix A-5

スポットライトによる物探し支援システム

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あらまし 隠れていても頻繁に移動する物でも、その物にスポットライトをあてるシステムを構築した。そのアプリケーションとして「部屋の中での紛失物探し」と「本棚での関連本探し」を支援するシステムを提案する。前者のシステムでは、音による物探し支援ツールとの比較実験から視覚情報による物探しの有効性を示す。後者ではシステムを使って本棚の前で技術調査をする実行例を提示する。

A Supporting System for Finding Lost Objects by Spotlight

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Abstract We developed a system that illuminates an object even though the object is hidden by others or often moved. We propose two systems as its application: finding lost objects in indoor and finding related books in bookshelf. In former system, we indicate advantages of our system against a system using acoustic awareness. In latter system, we present an example of using our system.

1 はじめに

紛失した携帯電話やテレビのリモコンなどを部屋の中を探し回ったり、以前に見た記憶のある本を本棚から探したり、「物探し」という行為はよく行われるものである。一方、物の位置を測定する機器は、近年その性能を向上させてきているが、決定的な機器はまだない。そこで本稿では、複数の位置測定器を併用し、物の位置への気づきを向上させることで探し物を支援するシステムを提案する。

物探しという問題を本稿では、「必要としている物がどこにあるか分からない」と定義する。この問題に我々は、システムが物の位置を常に計測し続け、ユーザから要求があった時に視覚情報（スポットライト）によりその位置を提示する、というアプローチをとる。システムが物探しを支援する場合には、人に機器を付けるか、物に機器を付けるか、によって分類できる。前者の場合は、ユーザの行動履歴から

記憶を想起させ、探し物のある場所を特定するやり方となる。後者の場合は、物の位置が既に分かっているため、必要な時にその場所を提示する、という方法になる。我々は、何も特別な機器を身につける必要がない後者の方法による解決を目的としている。また、探し物の位置を提示する方法には、視覚情報の利用だけでなく、音（聴覚情報）による通知もある。しかし、我々の目的とする視覚情報による通知は、「一目瞭然」というように物の位置を伝えることに対して有効性が高い、と考える。

物探し支援システムは、次の機能要件を充たす必要があると考える。

透過性 箱や鞆の中などの隠れた位置にある物を探し出せる機能

追従性 頻繁に移動する物を探し出せる機能

本稿では、これらの機能を充たしたスポットライトによる物探し支援システムを構築し、そのアプリ

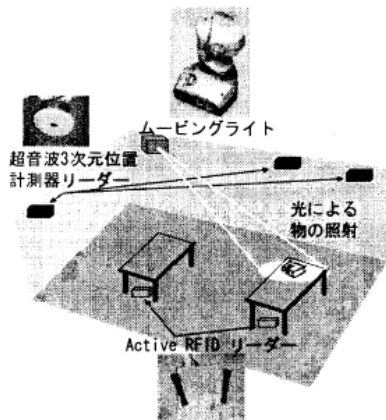


図 1: システム構成図

ケーションとして「部屋の中での紛失物探し (3 章)」と「書棚での関連本探し (4 章)」を提案する。

2 光による物探し支援システム

光による物探し支援システム [5] は、隠れた物でも頻繁に移動する物でもその位置を測定し、視覚情報によってユーザに知らせるシステムである。この章では、その構成、複数の位置計測器の統合方法、そして光の照射方法について記述する。

2.1 システム構成

図 1 に本システムのシステム構成を示す。物の場所を特定するための位置計測器として、2 種類の機器 (Active RFID: RF Code 社, 超音波位置計測器: 古河機械金属社) を併用する。それぞれの機器によって、位置情報の透過性 (隠れた状態にある物の位置を把握することが出来る機能) を実現し、測定精度の向上を図る。これらの 2 つの測定値の統合にはパーティクルフィルタを用いる。

探し物の位置への気付きを向上させるため、「スポットライト」を探し物のある付近に照射する。そのため、舞台などの照明機器として使用されているムービングライト (マーチン社) を用いる。

2.2 パーティクルフィルタによる物の位置推定

パーティクルフィルタとは、それぞれが状態と重みを持つ多数の粒子 (パーティクル) によって状態空間内全体の確率分布を近似する手法である。その特徴は、例えば位置推定に使用する場合、ある物がそこに存在する確率を検索領域のすべての箇所で計算せずに、局所的な箇所のみの計算で全体を近似できることである。Jeffrey Hightower らは、このパーティクルフィルタを物の位置推定に使用し、そのツールを公開している [2, 4]。本システムでは我々の使用する位置計測器についての部分をそのツールに付加し、使用している。パーティクルフィルタを位置推定に利用すると、精度の異なる位置情報の統合と隣接情報から位置情報への変換を統一的に処理することが可能となる。また、システムへ新たな位置計測機器を容易に導入することが出来るようになる。

本研究で使用した超音波位置計測器は、平均が 0 で 2 分散を測定誤差である 5cm とした正規分布として扱っている。Active RFID の場合は、事前実験から決定した誤差 20cm の幅と高さ (確率) 1/20 の一様分布としている。

2.3 ムービングライトによる光の照射

物の 3 次元位置情報が分かったら、そこに光が当たるようにムービングライトのパンとチルトを計算する。この計算は、パンとチルトを回転するアームと見ることにより、ロボットアームの手から腕の角度や伸縮を求める逆運動学問題 [9] と等価になる。

ムービングライトから見た座標系を T_m とし、その座標系での物の位置を P_m とする。一方、位置測定器から見た座標系を T_p とし、その座標系での物の位置を P_p とすると、物の位置の両者の関係は式 1 となる。

$$P_p = A_t A_{ry} A_{rz} A_{rp} A_{rt} P_m \quad (1)$$

各変換行列の意味は次のようである。座標系 T_p を平行移動 A_t , y 軸周りに回転 A_{ry} , z 軸周りに回転 A_{rz} するとムービングライトのパン、チルトが 0 の初期位置の座標系となる。その座標系からムービングライトのパン A_{rp} , チルト A_{rt} の変換をした座標系がムービングライト座標系 T_m となる。パーティクル

フィルタから得られた対象物の座標からムービングライトのパンとチルトを求めるには、機器の設置後のキャリブレーションとして求められた A_t, A_{ry}, A_{rz} と計測値から得られる P_m, P_p から A_{rp} と A_{rt} を求めればよい。

照射される光は、パーティクルフィルタによって計算される確率の分散に比例した大きさで照射する。色（無色）と形（円形）は変化しない。また、ムービングライトを制御するために、ムービングライトと計算機とのインターフェースには USITT DMX512¹ という標準のプロトコルを使用する。

3 部屋の中での紛失物探し

3.1 概要

部屋の中で見失った物を探すことを支援するシステムを光による物探し支援システムの1つ目のアプリケーションとして構築した。システムの実行例を図2に示す。Passive型RFIDタグを裏に貼り付けた紙に、タグを貼り付けた物の写真や、その物をイメージする絵を印刷したものを入力インターフェースとして使用している。RFIDリーダを絵の上に置くと、その物の付近をスポットライトが照射する。

3.2 音による紛失物探し支援ツールとの比較実験

表 1: 隠し場所タイプと、その時の光による物探し支援システムの位置測定精度の状態

Type	説明	位置精度状態
Type1	完全に目視できる。	高精度
Type2	一部が目視できる。	高精度
Type3	遮蔽物の下にある。遮蔽物を退かせば探し物を目視できる。	低精度
Type4	靴や箱の中。探し物を目視するまでにある程度の作業が必要。	低精度

¹ <http://www.usitt.org/standards/DMX512.html>

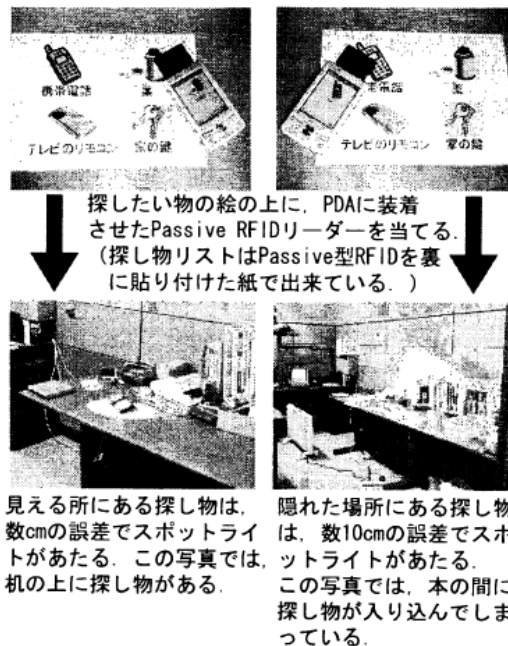


図 2: 紛失物探しシステムの実行例



図 3: 光による探し物支援システム（左）と、音による紛失物探し支援ツール（右）のタグ

物の位置情報の光による気づきは、音によるものに比べて有効であるかを調べるために、コントローラのボタンを押すとタグから音が発生するワイヤレスロケータ（The Sharper Image Inc.）という製品との比較実験を行った。

実験は、机や椅子などがある一般的なオフィス環境の中の約 4m 四方の領域に両システムのタグを隠し、被験者に探してもらいその時間を計測する。探してもらったタグは、図3のようである。タグは、表1で示す4つのタイプの隠し場所に隠しておく。被験者は実験環境に対して予備知識の無い大学院学生10人であり、隠し場所タイプ毎に3回、計12回の測定を両システムで行った。隠し場所毎に分類し

た結果を図4に示す。図4のエラーバー（棒の先端の工の形をしたもの）は平均値の95%信頼区間を示している。結果は、Type2のみに両側1%水準で有意差があると確認された。この結果から光による物探し支援システムの優位性は、手などを使わずに視覚情報だけで探し物が出来る条件で、探し物が分かり難い所にある場合であると確認できた（図5）。

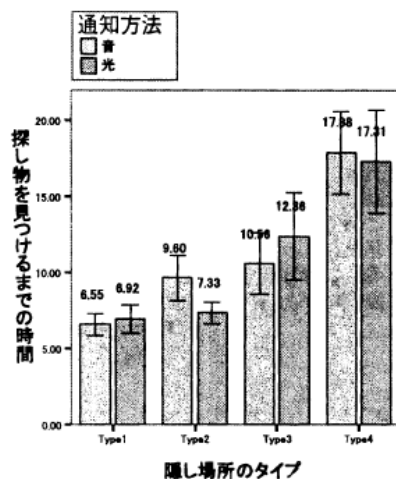


図4: 隠し場所タイプ毎の物を見つけるまでの時間(秒)

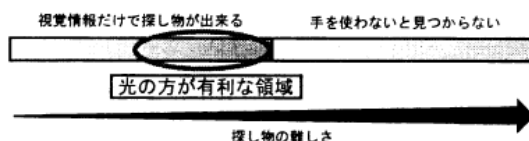


図5: 音に対しての光による物探し支援システムの優位性

4 本棚での関連本探し

4.1 概要

書店や図書館の前で、例えば何かについて調査をしている時に、いくつもの本を手にとって見る、ということをよく行うものである。この時には、Amazon.comなどで提供されている「この本を購入した人は、よくこういう本も購入しています」という情

報が役に立つ。ここでは、このような情報を光による物探し支援システムを使って、計算機を意識せずにユーザに伝える「本棚での関連本探し支援システム」について記述する。

システムは次節以降で説明する「関連本検索」「学習による関連本検索」「部分ネットワークによるランキング表示」の3つの機能を提供する。ユーザは、実物の本を指定位置にかざすことでシステムへ入力情報を与え、スポットライトで実物の本を照らし詳細情報をディスプレイに表示することでシステムからの出力情報を得る。

4.2 関連本検索

Amazon.comから提供されているWeb Service²を使用して、「この本を買った人はこんな本も買っています」と紹介されている³5つの本(XMLのタグは「SimilarProducts」)を関連本元データとして取得する。本棚にあるすべての本について2つ先まで関連本元データを取得し、ノードが「本」でエッジが「本の関係」を表す有向グラフを作成する（この有向グラフは以降のアルゴリズムでも使用する）。

入力データとして1つの本をシステムに与えると、それに関連する本を1つ出力する。ここでは関連本の事を、予め作られた関連本元データの有向グラフ上で最も少ないリンク数で結ばれる2つの本である、と定義する。ディスプレイに関連本とそこまでのリンク情報が表示され、実物の関連本にはスポットライトがあたる。

4.3 学習による関連本検索

学習による関連本検索は、2冊の本から関係を学習し、その関係を使って関連本を検索することである。この学習は次のようにして行われる。

STEP1 関連本元データの有向グラフを表す隣接行列を固有値分解し、最大と第二最大固有値を持つ固有ベクトルを使い、全ての本を平面配置する。

STEP2 2つの本の位置を示すベクトルの減算で得るベクトルをその2冊の関係とする。

² <http://www.amazon.com/gp/aws/sdk/>

³ 2005年2月現在の情報

STEP3 与えられた本にSTEP2のベクトルを足し、仮想的な関連本を作る。

STEP4 仮想的な関連本に最も近い本を推薦する。

出力は、ディスプレイに仮想的な関連本に類似する順番で本が表示される。その中の1冊を選択すると、実物にスポットライトが当たる。

4.4 部分ネットワークによるランキング表示

指定された本の中での重要度は、関連本元データの有向グラフを表現する隣接行列の最大固有値を持つ固有ベクトルの値の大きさに決定する。この方法は、Googleでの検索結果をランキングするアルゴリズム (PageRank [6]) として知られている。

指定された本から2リンク先までの関係ネットワークにPageRankを適用することで、特定領域内でのランキングを推定することが出来る。例えば、Amazon.comには売り上げランキングが表示されているのであるが、これはすべての本とすべてのユーザによる指標で、それがそのまま自分にとって重要な本であることを示しているわけではない。一方、自分で本を指定してPageRankを適用することは、それらの本とその周辺ではどの本が重要であるかが分かり、前者の方法よりは自分に適した重要度を教えてくれると思われる。

システムへの入力、指定位置にランキングしたい本を1つづつかざし、最後にディスプレイ上のランキングボタンをクリックする。ランキングがディスプレイ上に現れ、その中の1冊を選択すると実物にスポットライトが当たる。

4.5 実行例：ネットワーク分析関連の本を探す

図6に本棚での関連本探し支援システムを使用した例を示す。閲覧のスタートは、「Social Network Analysis: Methods and Applications (Structural Analysis in the Social Sciences, 8) (ISBN0521387078)」からで、「実践ネットワーク分析—関係を解く理論と技法 (ISBN4788507811)」を関連本検索で推薦される。学習による関連本検索機能に「自然科学の統計学 (ISBN4130420674)」, 「統

計学入門 (ISBN4130420658)」と与え「実践ネットワーク分析—関係を解く理論と技法」の入門編にあたる「ネットワーク分析—何が行為を決定するか (ISBN4788505843)」を見つける。最後にすべての本をランキング表示し、「ネットワーク分析—何が行為を決定するか」が最も重要であるという結果を得る。

5 関連研究

透過性と追従性を持った「聴覚情報」による物探し支援は、[10]で提案されている。視覚情報を使った物探し支援システムとしては、店舗内での商品探しを可動式プロジェクタを使って支援するシステムがある[7]。しかしこのシステムでは物の位置情報を静的に扱っているため追従性の機能を持っていない。

計算機上に仮想図書館を作り関連する図書などを推薦する研究は、例えば[3]などがある。一方、我々のシステムと同様に実世界志向の支援システムとしては、図書館でヘッドマウントディスプレイを使って現実を拡張するシステムが提案されている[8]。我々のシステムとの相違点は、我々のシステムは何も機器を身に着ける必要が無いことである。図書館で本探しを支援する[1]のシステムは、現実世界の活性化を目的とし何も身に着ける必要がないのであるが、システムが透過性と追従性の機能を持っていない。

6 おわりに

視覚情報を用いた「透過性」「追従性」を持つ光による物探し支援システムを提案し、そのアプリケーションとして「部屋の中での紛失物探し」と「本棚での関連本探し」の2つを構築した。今後は、さらに改良し、評価をしていきたいと考える。

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図 6: 本棚での関連本探し支援システムの実行例

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Appendix B

JAMES L. MULLINS, PhD

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ph. 765 479 4956

Prior Art Documentation Librarian Services, LLC. (PADLS). Founded January 2018. As of July, 2023, 1 have completed 123 declarations for 39 law firms; five depositions were scheduled, three cancelled a few days prior, one was held in February, 2019 and a second was held in June 2023.

Library Experience:

2018-present Dean Emeritus, Libraries & Norton Professor Emeritus, Purdue University
2011 - 2017 Dean of Libraries & Esther Ellis Norton Professor, Purdue University
2004 - 2011 Dean of Libraries & Professor, Purdue University, West Lafayette, IN
2000-2004 Assistant/Associate Director for Administration, MIT Libraries, Massachusetts Institute of Technology, Cambridge, MA.
1996-2000 University Librarian & Director, Falvey Memorial Library. Villanova University, Villanova, PA.
1978-1996 Director of Library Services, Indiana University South Bend.
1974-1978 Associate Librarian, Indiana University Bloomington, School of Law.
1973-1974 Instructor/Catalog Librarian. Georgia Southern College (now University).

Teaching Experience:

1977-1996 Associate Professor (part-time), School of Library and Information Science, Indiana University. Subjects taught: Cataloging, Management, and Academic Librarianship.

Education:

1972 - University of Iowa. Honors Bachelor of Arts, History, Religion & Political Science.
1973 - University of Iowa. Master of Arts in Library Science.
1984 - Indiana University. Doctor of Philosophy. Concentration: Academic Library Administration. Emphasis: Law Librarianship.

Awards and Recognition:

2017 Wilmeth Active Learning Center/Library of Engineering and Science, Grand Reading Room, was announced by President Mitch Daniels, Purdue University, that it would be re-named the James L. Mullins Reading Room to honor his leadership and reputation in the academic library profession.

September 2017. Portrait unveiled December 2017.

2017 Distinguished Alumnus Award by the School of Informatics and Computing, Indiana University, Bloomington. Given June 25, 2017.

2016 Hugh C. Atkinson Memorial Award, jointly sponsored by the four divisions of the American Library Association (ALA), June 27, 2016.

2015 ACRL Excellence in University Libraries Award, April 23, 2015.

Named Esther Ellis Norton Professor of Library Science by Purdue Trustees, December 11, 2011.

International Review Panel to evaluate the University of Pretoria Library, February 20 – 24, 2011. Pretoria, South Africa.

Publications: (selected)

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“How Long the Odyssey? Transitioning the Library and Librarians to Meet the Needs and Expectations of the 21st Century University,” David Kaser Lecture, School of Informatics & Computing, Indiana University, Bloomington, IN, November 16, 2015.

Presentation at University of Cape Town, Cape Town, South Africa, August 20, 2015.

“The Challenge of Discovering Science and Technology Information,” Moderator, International Federation of Library Associations (IFLA) Science and Technological Libraries Section Program, Cape Town, South Africa, August 18, 2015.

“An Odyssey in Data Management: Purdue University,” International Federation of Library Associations (IFLA) Research Data Management: Finding Our Role – A program of the Research Data Alliance, Cape Town, South Africa, August 17, 2015.

Presentation at University of Pretoria, Pretoria, South Africa, August 11, 2015.

Co-Convener with Sarah Thomas, Harvard University, at the Harvard Purdue Symposium on Data Management, Harvard University, Cambridge, MA, June 15-18, 2015.

“Strategic Communication,” panel discussion on the Director's role and perspective on library communications at Committee on Institutional Cooperation (CIC) Center for Library Initiatives (CLI) Annual Conference, University of Illinois Urbana-Champaign, May 20, 2015.

“Issues in Data Management,” panel discussion moderated by Catherine Woteki, United States Undersecretary for Research, Education & Economics at 20th Agriculture Network Information Collaborative (AgNIC) Annual Meeting in the National Agricultural Library, Beltsville, MD, May 6, 2015.

“Active learning/IMPACT & the Active Learning Center at Purdue University,” Florida Institute of Technology, Melbourne, FL, February 11, 2015.

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“Purdue University The Active Learning Center—A new concept for a library,” Association of University Architects 59th Annual National Conference, University of Notre Dame, South Bend, IN, June 23, 2014.

“Big Data & Implications for Academic Libraries,” keynote speaker, Greater Western Library Alliance (GWLA) Cyber-infrastructure Conference, Kansas City, MO, May 28, 2014.

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“Getting on Track with Tenure,” Association of College and Research Libraries (ACRL) Research Program Committee. Washington, DC, June 26, 2011.

“Integration of the Press and Libraries Collaboration to Promote Scholarly Communication,” Association of Library Collections & Technical Services (ALCTS) Scholarly Communication Interest Group – American Library Association, New Orleans, Louisiana, June 25, 2011.

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“Are MLS Graduates Being Prepared for the Changing and Emerging Roles that Librarians must now assume within Research Libraries?” University of Oklahoma Libraries Seminar, March 4, 2011, Oklahoma City, Oklahoma.

“The Future Role of University Librarians,” the University of Cape Town, South Africa, February 25, 2011.

“New Roles for Librarians: the Application of Library Science to Scientific/Technical Research – Purdue University – a case study. International Council for Science and Technology (ICSTI); Ottawa, Canada. June 9, 2009.

“Reinventing Science Librarianship: Models for the Future,” Association of Research Libraries / Coalition for Networked Information. October 16-17th, 2008, Arlington, VA. Moderator and convener of Data Curation: Issues and Challenges.

“Practical Implementation and Opportunities Created at Purdue University,” African Digital Curation Conference, Pretoria, South Africa, (live video transmission), February 12, 2008.

Keynote speaker. “*Scholarly Communication & Academe: The Winter of Our Discontent*,” XXVII Charleston Conference on Issues in Book and Serial Acquisition, Charleston, South Carolina. November 8, 2007.

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ARL Workshop on New Collaborative Relationships: The Role of Academic Libraries in the Digital Data Universe, September 26-27, 2006, Arlington, VA. Invited participant.

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“Leadership for Learning: Building a Culture of Teaching in Academic Libraries – an administrative perspective,” American Library Association, Association of College and Research Libraries, Instruction Section, Annual Conference, New Orleans, June 25th, 2006.

“Building an interdisciplinary research program in an academic library: how the Libraries’ associate dean for research makes a difference at Purdue University,” International Association of Technological University Libraries (IATUL), Porto, Portugal, May 23rd, 2006.

“Enabling Interaction and Quality in a Distributed Data DRIS,” *Enabling Interaction and Quality: Beyond the Hanseatic League*. 8th International Conference on Current Research Information Systems, with D. Scott Brandt and Michael Witt. Promoted by euro CRIS, Bergen, Norway, May 12th, 2006, Brandt, and Witt presented in person

“Interdisciplinary Research,” with D. Scott Brandt, Coalition for Networked Information (CNI) Spring Meeting: Project Briefing, Washington, D.C., April 3rd, 2006.

“An Interview with Purdue’s James Mullins,” a podcast submitted by Matt Pasiewicz, on *Educause Connect*, http://connect.educause.edu/James_L_Mullins_Interview_CNI_2005

“Managing Long-Lived Digital Data-sets and their Curation: Interdisciplinary Policy Issues,” Managing Digital Assets Forum, Association of Research Libraries (ARL), Washington, D.C., October 28th, 2005.

“The Odyssey of a Librarian.” Indiana Library Federation (ILF), District 2 Meeting, South Bend, Indiana. October 4th, 2005.

"New College Library Standards," Standards Committee Presentation, ALA, Chicago, July 7, 2000. SUNY Library Directors, Lake George, New York. “*The College Library Standards: a Tool for Assessment.*” April 5, 2000.

Tri-State College Library Association, *Finding You Have Talents You Never Knew You Had*, Penn State Great Valley, March 25, 2000.

Using Web Statistics, American Library Association, New Orleans, June 24, 1999.

Keynote speaker at the JSTOR Workshop, January 29, 30, 1999. University of Pennsylvania, Philadelphia, PA.

"The New Standards for Electronic Resources Statistics," Society of Scholarly Publishers, Washington, D.C., September 17, 1998.

"Evaluating Online Resources: Now that you've got them what do you do?," joint presenter with Chuck Hamaker, LSU, at the NASIG Conference, Boulder, Colorado. June 1998.

"What Employers Are Looking for in New Librarians?" Pennsylvania Library Association, Philadelphia. September 26, 1997.

"The Theory of Matrix Management" panel presentation of the Comparative Library Organization Committee of the Library Organization and Management Section of the Library Administration and Management Association, a division of the American Library Association, Annual Meeting, Chicago, June 24, 1990.

Professional Involvement: (summary of recent emphasis)

The focus for my professional involvement and research has moved recently toward managing massive data-sets. This has resulted in working with faculty in the sciences and technology to determine how librarians can collaborate in managing, curating, and preserving data-sets for future access and documentation. This has included various speaking opportunities as well as participation in planning with the National Science Foundation (NSF) on ways in which librarians can be integrated more completely into the funded research process. Participation in the Kanazawa Institute of Technology/Council of Library Resources Roundtable was particularly rewarding and provided new opportunities to share with international colleagues the issues surrounding data-set management. I was

the champion for the creation of the Distributed Data Curation Center (D2C2) at Purdue University (<http://d2c2.lib.purdue.edu/>)

Throughout my career, beginning with my dissertation, I have been actively involved with assessing and evaluating libraries. In the fall of 1999, I contacted twenty-two academic library directors to determine whether the need was also felt by others. The response was overwhelmingly affirmative. This resulted in a meeting at ALA Midwinter, January 2000. A formal meeting followed at Villanova University in April 2000. As convener, I helped to form the University Libraries Group (ULG), modeled after the Oberlin Group for college libraries. The ULG is made up of university libraries that support diverse wide-ranging programs through doctoral level and have a level of support that places them in the top tier of academic institutions. A few of the member libraries, along with Villanova, are William and Mary, Wake Forest, Lehigh, Carnegie-Mellon, Tufts, Marquette, Miami of Ohio, and Southern Methodist. In 1994 appointed to the Standards Committee, College Section, Association of College and Research Libraries. During the next six years, the Committee concentrated on changing the focus of the standards from quantitative analysis of input and output factors to emphasis on assessment of the outcome. Culmination of the work was a re-issue of the *Standards for College Libraries* in 2000. The knowledge gained through my work experience enabled me to formulate the changes needed in the standards. This work allowed for close collaboration with accrediting agencies, both professional and regional. During this same time another focus emerged, the impact of digital resources. Through my work on the JSTOR Statistics Task Force, standards were developed on the collection of use of electronic databases. This Standard was later adopted in 1998 by the International Consortium of Library Consortia (ICOLC). In 2002, the American Library Association appointed me to serve as the liaison to the Marketing and Management Section of the International Federation of Library Associations (IFLA).

Professional Service: (representative list)

Nominations Committee, Association of Research Libraries (ARL), 2016.

Steering Committee, Scholarly Publishing and Academic Resources Coalition (SPARC), 2016 – 2017.

“Excellence in Library Services,” Chair, Review Team, University of Hong Kong, Hong Kong, August 24-27, 2015.

Chair, Management Advisory Board, 2015-2017; Member, Scientific Advisory Board, arXiv, Cornell University, 1/1/2013 – present.

Advisory Board for the Wayne State University School of Library and Information Science, July 2012 – present.

Advisory Board for Microsoft Academic Search, 2012 – 2015. Redmond, WA.

Transforming Research Libraries, a Strategic Direction Steering Committee of the Association of Research Libraries (ARL), 2012-2015.

Science and Technology section, representing ARL, International Federation of Library Associations (IFLA), Chair, 2013 – 2017; Member, 2011 to present.

Member of University of Pretoria, South Africa, Library Review Committee. August 2013.

Co-chair, Local Arrangements Planning Committee for 2013 Conference, Association of College and Research Libraries (ACRL), a division of the American Library Association (ALA).

Association of Research Libraries Leadership & Career Development Program Mentor, 2011-2017.

e-Science Task Force, Association of Research Libraries. July 2006 – present. Chair, October 2011 – October 2012.

Board of Directors, International Association of Technological University Libraries (IATUL). January 2008 – December 2014.

Midwest Collaborative for Library Services (MCLS); Board Member, October 2010 – December 2012.

Chair, Library Directors, Committee on Institutional Cooperation (CIC), July 2010 – June 2012.

Board of Directors, Association of Research Libraries (ARL); October 2008 – October 2011.

Scholarly Communication Steering Committee, Association of Research Libraries (ARL) 2008-2011.

Editorial Board, *College and Research Libraries*, Association of College and Research Libraries, American Library Association. January 2008 – December 2014.

Chair, Organizing Committee for IATUL Conference 2010, June 21-24, 2010, Purdue University, West Lafayette, Indiana/Chicago, Illinois.

Conference Planning Committee for National Conference of the Association of College and Research Libraries, 2009, Seattle, Washington.

Research Committee, Association of College and Research Libraries, ACRL, division of ALA. 2002-2007, chair, 2005-2007.

Association of Research Libraries, Search and Screen Committee, Executive Director. March – January 2008.

Center for Research Libraries, Board of Directors. April 2006 – April 2012.

Academic Libraries of Indiana, Board of Directors, 2004 – present. Vice-president, 2005-2007.

President, 2007- 2009.

ALA Representative to the International Federation of Library Associations (IFLA), Marketing and Management (M&M) Section, initial term 2003-2007, re-appointed for second term, 2007-2011.

Invited to represent Research Libraries at the ACRL/3M Wonewok Retreat to assess Marketing of Academic Libraries, October 2002.

Hugh A. Atkinson Award Committee, LAMA Representative, ALA, 2001-2005.

Program Committee, Library Administrators and Management Association (LAMA), a division of ALA. 1996-2001.

ACRL, Standards and Accreditation Committee, a division of ALA. Liaison to RBMS Section of ACRL. 1997-2002.

Elected to the Executive Committee of LAMA, LOMS, a division of the American Library Association, 1998-2000. Nominated as Chair/Elect for 2003 – 2005.

Columbia University Press Advisory Committee. 1996 - 2000.

LITA/LAMA Conference Evaluation Committee, Pittsburgh, Pennsylvania, October 1996.

"New Learning Communities," Coalition for Networked Information, Indianapolis. November 19-21, 1995. Facilitator for invitational, national conference committed to developing collaborative learning and teaching techniques, involving librarians.

Planning Committee-Evaluation. LITA/LAMA 1996 Conference, Pittsburgh. This first conference, to be held jointly between two divisions of ALA, will focus on new technologies within libraries.

Indiana Cooperative Library Services Authority (InCoLSA), elected to Executive Committee, April 1991, served as President in 1993-94. InCoLSA is a statewide network of academic, public, school, and special libraries that supports library cooperation for cataloging, interlibrary loan, collection development and application of new technologies.

Governor's Conference on Libraries and Information Services. Served on Planning Committee, Academic Libraries Representative, appointed by the Governor to represent academic libraries in Indiana, Chair, Finance Committee, April 1989-July 1991.

Indiana Library Endowment Foundation Board, 1984-92. Charter Member, 1984, President, 1988-1992. 2004-2005.

University Service: (Summary)

Served on search and screen committees for senior positions including chancellor, dean, and directors; most recently I have been asked to serve on the search committee for the provost of Purdue University. At MIT service included the Library Council & appointment to the Administrative Council by President

Vest, 2001-2003 & Member of the Faculty Committee on the Library System. At Purdue appointed by the President to the Search Committee for the Provost, October 2007 to May 2008; member of the Capital Projects Committee, and IT Operational Oversight Committee as senior academic dean, 2008-2014.

Global Council, Global Policy Institute, 2012 – 2016.

Academic Program Excellence and Rankings (APER) project team, 2014.

Representative of the Academic Deans on the Re-engineering Business Operations, Purdue University, 2016 –

Academic Deans Council chaired by Provost – 2004 – 2017.

University Promotion and Tenure Committee – 2006 – 2017.

"Outstanding Team Award, Electronic Reserve Project," served as Chair, recognition awarded by the President of Villanova University to one team who made an outstanding contribution to the operations of the University, selected by a committee of administrators, faculty, and staff. Awarded September 9, 1999.

Nominated for the IUSB Lundquist Award, 1995 & 1996. The Lundquist award is given to faculty who have "exhibited excellence in teaching, scholarly or artistic achievement, and diversified relevant service..."