

SPIE Medical Imaging 50th anniversary: history of the Picture Archiving and Communication Systems Conference

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Abstract. To commemorate the SPIE Medical Imaging 50th anniversary, this article provides a brief review of the Picture Archiving and Communication Systems (PACS) and Informatics conferences. Important topics and advances, contributing researchers from both academia and industry, and key papers are noted. © *The Authors. Published by SPIE under a Creative Commons Attribution 4.0 International License. Distribution or reproduction of this work in whole or in part requires full attribution of the original publication, including its DOI.* [DOI: [10.1117/1.JMI.9.S1.S12210](https://doi.org/10.1117/1.JMI.9.S1.S12210)]

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1 Introduction

Picture archiving and communication systems (PACS) and imaging informatics have been topics covered in forty of the past fifty years of the SPIE Medical Imaging symposium. PACS or medical image management systems were developed to electronically acquire, archive, transmit, and display medical images, providing cost-effective storage and retrieval of radiologic examinations, and simultaneous access to studies from multiple locations. PACS ultimately enabled the transition of medical imaging, and radiology in particular, from an analog film-based operation to a digital workflow. The resulting treasure troves of digital medical images are now accessible from secure cloud storage devices over ubiquitous reliable networks and can be viewed on inexpensive electronic display devices. With the use of today's highly performant computer graphics processing units (GPUs), computer image processing and analysis algorithms and machine and deep learning applications can be translated from the research laboratory to the clinical arena.

Initial concepts for PACS were introduced at the 1981 SPIE "First International Conference and Workshop on PACS" and presented papers were published in a proceedings in 1982. The PACS conference name has been modified multiple times over the years to reflect the important research activities of the period (Table 1), and some previously covered topics were moved to other newly formed SPIE Medical Imaging conferences, such as Image Perception, Computer-Aided Diagnosis, and Digital Pathology, as paper submissions in those areas increased.

The SPIE Medical Imaging symposia have been excellent forums for commingling of academic and industry researchers, while also providing a suitable environment at which students, postdoctoral fellows, and junior faculty could present their first research paper or poster. For the first decade of SPIE Medical Imaging PACS meetings, the conference proceedings were one of the few scientific venues in which to publish PACS and imaging informatics research.

This article reviews the forty-year history of the PACS and Imaging Informatics conferences as part of the SPIE Medical Imaging symposia. Important topics and advances are highlighted, and contributing researchers from both academia and industry are noted along with key research papers.

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Table 1 PACS Conference names, year, volume number, location, conference co-chairs, and number of papers. PACS-specific conference titles appear in bold; italic titles denote a name change (PACS: Picture Archiving and Communication Systems).

Year	Volume	Location	Conference name	Co-chairs	# of papers
1981	0318	Newport Beach, CA	1st International Conference and Workshop on PACS	Andre J. Duerinckx	83
1982	0372	Pacific Grove, CA	Intl. Workshop on Physics and Engineering in Medical Imaging	Orhan Nalcioglu	40
1983	0418	Kansas City, KS	PACS II	Samuel J. Dwyer III	45
1984	0486	Las Vegas, NV	Medical Imaging and Instrumentation '84	James A. Mulvaney	32
1984	0515	Arlington, VA	Medical Images and Icons	Andre J. Duerinckx, Murray H. Loew, Judith M.S. Prewitt	64
1985	0536	California	3rd Intl Conference on PACS	Samuel J. Dwyer III, Robert J. Schneider	34
1985	0555	Boston, MA	Medical Imaging and Instrumentation '85	James A. Mulvaney	36
1986	0671	Newport Beach, CA	Physics and Engineering of Computerized Multidimensional Imaging and Processing	Thomas F. Budinger, Zang-Hee Cho, Orhan Nalcioglu	43
1987	0767	Newport Beach CA	Medical Imaging I	Samuel J. Dwyer III, Roger H. Schneider	55
1988	0914	Newport Beach CA	Medical Imaging II	Samuel J. Dwyer III, Roger H. Schneider	188
1989	1093	Newport Beach CA	Medical Imaging III: PACS System Design and Evaluation	Samuel J. Dwyer III, R. Gilbert Jost, Roger H. Schneider	69
1990	1234	Newport Beach, CA	Medical Imaging IV: PACS System Design and Evaluation	Samuel J. Dwyer III, R. Gilbert Jost	113
1991	1446	San Jose, CA	Medical Imaging V: PACS Design and Evaluation	Samuel J. Dwyer III, R. Gilbert Jost	57
1992	1654	Newport Beach, CA	Medical Imaging VI: PACS Design and Evaluation	R. Gilbert Jost	69
1993	1899	Newport Beach, CA	<i>Medical Imaging 1993: PACS Design and Evaluation</i>	R. Gilbert Jost	68
1994	2165	Newport Beach, CA	Medical Imaging 1994: PACS Design and Evaluation	R. Gilbert Jost	97
1995	2435	San Diego, CA	Medical Imaging 1995: PACS Design and Evaluation: Engineering and Clinical Issues	R. Gilbert Jost, Samuel J. Dwyer III	67
1996	2711	Newport Beach, CA	Medical Imaging 1996: PACS Design and Evaluation: Engineering and Clinical Issues	R. Gilbert Jost, Samuel J. Dwyer III	66
1997	3035	Newport Beach, CA	Medical Imaging 1997: PACS Design and Evaluation: Engineering and Clinical Issues	Steven C. Horii, G. James Blaine	78

Table 1 (Continued).

Year	Volume	Location	Conference name	Co-chairs	# of papers
1998	3339	San Diego, CA	Medical Imaging 1998: PACS Design and Evaluation: Engineering and Clinical Issues	Steven C. Horii, G. James Blaine	65
1999	3662	San Diego, CA	Medical Imaging 1999: PACS Design and Evaluation: Engineering and Clinical Issues	G. James Blaine, Steven C. Horii	52
2000	3980	San Diego, CA	Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues	G. James Blaine, Eliot L. Siegel	55
2001	4323	San Diego, CA	Medical Imaging 2001: PACS and Integrated Medical Information Systems: Design and Evaluation	Eliot L. Siegel, H. K. Huang	56
2002	4685	San Diego, CA	Medical Imaging 2002: PACS and Integrated Medical Information Systems: Design and Evaluation	Eliot L. Siegel, H. K. Huang	54
2003	5033	San Diego, CA	Medical Imaging 2003: PACS and Integrated Medical Information Systems: Design and Evaluation	H. K. Huang, Osman M. Ratib	57
2004	5371	San Diego, CA	Medical Imaging 2004: PACS and Imaging Informatics	Osman M. Ratib, H. K. Huang	48
2005	5748	San Diego, CA	Medical Imaging 2005: PACS and Imaging Informatics	Osman M. Ratib, Steven C. Horii	63
2006	6145	San Diego, CA	Medical Imaging 2006: PACS and Imaging Informatics	Steven C. Horii, Osman M. Ratib	43
2007	6516	San Diego, CA	Medical Imaging 2007: PACS and Imaging Informatics	Steven C. Horii, Katherine P. Andriole	50
2008	6919	San Diego, CA	Medical Imaging 2008: PACS and Imaging Informatics	Katherine P. Andriole, Khan M. Siddiqui	43
2009	7264	Lake Buena Vista, FL	Medical Imaging 2009: Advanced PACS-based Imaging Informatics and Therapeutic Applications	Khan M. Siddiqui, Brent J. Liu	36
2010	7628	San Diego, CA	Medical Imaging 2010: Advanced PACS-based Imaging Informatics and Therapeutic Applications	Brent J. Liu, William W. Boonn	38
2011	7967	Lake Buena Vista, FL	Medical Imaging 2011: Advanced PACS-based Imaging Informatics and Therapeutic Applications	William W. Boonn, Brent J. Liu	36
2012	8319	San Diego, CA	Medical Imaging 2012: Advanced PACS-based Imaging Informatics and Therapeutic Applications	William W. Boonn, Brent J. Liu	34
2013	8674	Lake Buena Vista, FL	Medical Imaging 2013: Advanced PACS-based Imaging Informatics and Therapeutic Applications	Maria Y. Law, William W. Boonn	32
2014	9039	San Diego, CA	Medical Imaging 2014: PACS and Imaging Informatics: Next Generation and Innovations	Maria Y. Law, Tessa S. Cook	29

Table 1 (Continued).

Year	Volume	Location	Conference name	Co-chairs	# of papers
2015	9418	Orlando, FL	Medical Imaging 2015: PACS and Imaging Informatics: Next Generation and Innovations	Tessa S. Cook, Jianguo Zhang	37
2016	9789	San Diego, CA	Medical Imaging 2016: PACS and Imaging Informatics: Next Generation and Innovations	Jianguo Zhang, Tessa S. Cook	32
2017	10138	Orlando, FL	Medical Imaging 2017: Imaging Informatics for Healthcare, Research and Applications	Tessa S. Cook, Jianguo Zhang	41
2018	10579	Houston, TX	Medical Imaging 2018: Imaging Informatics for Healthcare, Research and Applications	Jianguo Zhang, Po-Hao Chen	58
2019	10954	San Diego, CA	Medical Imaging 2019: Imaging Informatics for Healthcare, Research and Applications	Po-Hao Chen, Peter R. Bak	48
2020	11318	Houston, TX	Medical Imaging 2020: Imaging Informatics for Healthcare, Research and Applications	Po-Hao Chen, Thomas M. Deserno	45
2021	11601	Virtual Online	Medical Imaging 2021: Imaging Informatics for Healthcare, Research and Applications	Thomas M. Deserno, Brian J. Park	32
2022	12037	San Diego and Podcast	Medical Imaging 2022: Imaging Informatics for Healthcare, Research and Applications	Thomas M. Deserno, Brian J. Park	32 8

2 1980s PACS Conferences

2.1 1981

Andre J. Duerinckx (Philips Ultrasound, Inc) chaired the “ First International Conference and Workshop on PACS” held in January of 1981 at Newport Beach, California. Eighty-three papers were presented and subsequently published in a proceedings in January 1982. Multiple papers included PACS concept descriptions and prototype architectures including accounts by Dwyer and Templeton (University of Kansas),^{1,2} Duerinckx (Philips Ultrasound, Inc.),³ Vizy (Eastman Kodak),⁴ Staab (University of North Carolina),⁵ Bohm (Institut fur Mathematik and Datenverarbeitung in der Medizin, Germany),⁶ and Blaine and Jost (Washing University St Louis).⁷ Horii (New York University) discussed the cost of PACS,⁸ and Arenson (University of Pennsylvania) detailed radiology information system management⁹ and fiber optic networks for data communication.¹⁰ Skinner (MITRE Corporation) described technologies for teleradiology.¹¹ Blom (Philips Labs, US)¹² and Billingsley (Jet Propulsion Lab)¹³ reported on optical disc and magnetic tape storage, respectively. Schneider (Food and Drug Administration)¹⁴ and Prewitt (National Institutes of Health)¹⁵ discussed the need for standards prior to the formation of the ACR-NEMA (American College of Radiology-National Electronic Manufacturers Association) committee which ultimately evolved into the Digital Imaging and Communications in Medicine (DICOM) standards committee. Other topics appearing in the first PACS conference included two papers on perception, three covering legal aspects of PACS, and six described modality mini-PACS. Figure 1 (top) shows the distribution of topics presented at the first PACS conference in 1991. In addition to paper presentations, two workshops were held including a panel of equipment manufacturers who presented their views on PACS¹⁶ and a panel representing the medical

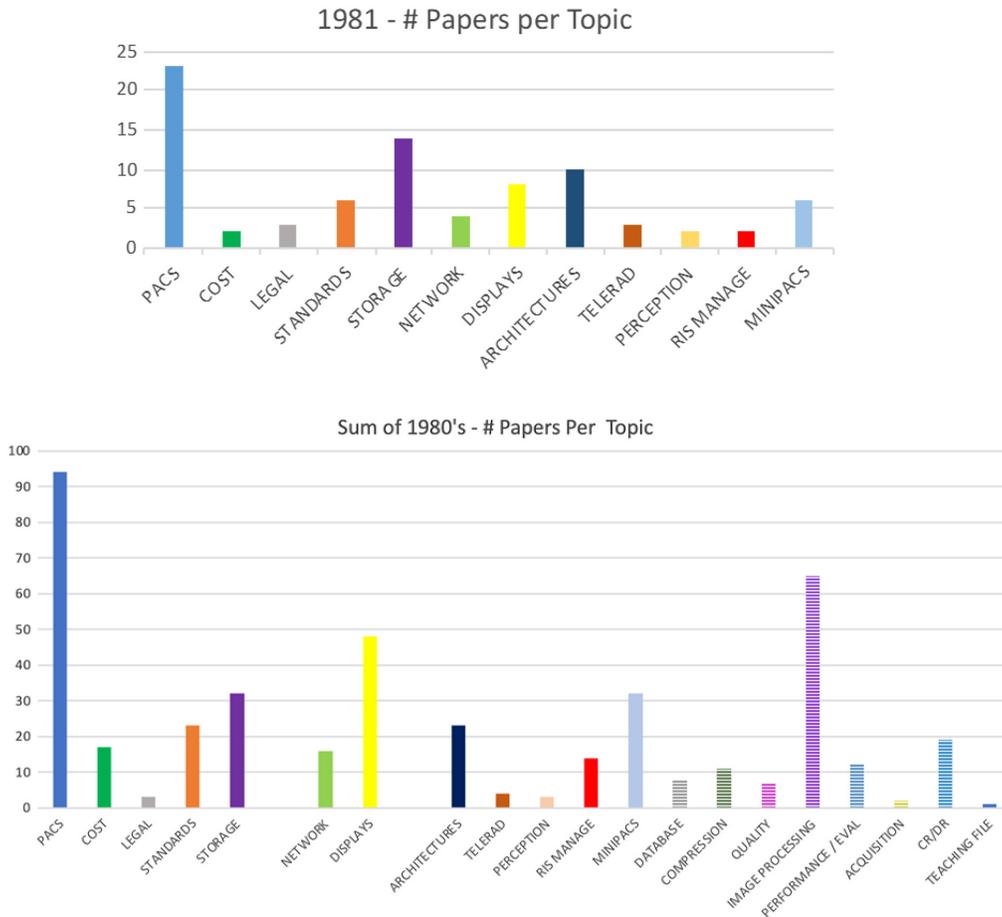


Fig. 1 Distribution of topics presented at the 1982 PACS conference (top) and the sum of topics presented during the 1980 meetings (bottom). The last eight topics to the right (horizontal line fill) are new topics from year one.

community’s view on PACS.¹⁷ The above authors and their home institutions representing academia and industry, US and international researchers, were among the early PACS pioneers.

2.2 1982

No PACS-specific conference was held in 1982 but the “International Workshop on Physics and Engineering in Medical Imaging” was held in Pacific Grove, California, and chaired by Orhan Nalcioğlu. Several papers covered digital projection radiography.¹⁸

2.3 1983

“Picture Archiving and Communication Systems (PACS II)” was held in Kansas City, Kansas, and chaired by Samuel J. Dwyer III. Many papers presented general PACS concepts^{19–24} with some focusing on the display piece with observations that better functionality was required to move PACS forward.^{25–29} The importance of databases^{30,31} and radiology information system (RIS) functionality were noted as well as the need for standards^{32,33} and studies of image quality.³⁴ Networking,^{35,36} storage media^{37–39} and the use of compression^{40,41} were included. H.K. Huang’s laboratory (UCLA) presented multiple papers on PACS design and implementation.⁴²

2.4 1984

The next PACS-specific conference was not held until 1985 but two other relevant conferences had active participation. The “Medical Imaging and Instrumentation ‘84” conference chaired by

James A. Mulvaney was held in Las Vegas, Nevada, in April and the “Medical Images and Icons” chaired by Andre J. Duerinckx, Murray H. Loew and Judith MS Prewitt was held in Arlington, Virginia, in July. Digital projection radiography^{43,44} and digital image display quality⁴⁵⁻⁵⁶ were several of the topics addressed at the “Medical Imaging and Instrumentation” meeting. At the “Medical Images and Icons” conference, image processing papers appeared prominently, as did image display including 3D,⁴⁷⁻⁴⁹ PACS design concepts,⁵⁰⁻⁵⁴ image acquisition,^{55,56} standards,⁵⁷ display design,⁵⁸⁻⁶⁰ and networking.⁶¹ A paper on archival media that described an optical disk that could store 15,000 CT images⁶² was presented. Commercial challenges for PACS were reported on,⁶³ and several mini-PACS including for pathology images were discussed.^{64,65} One paper used artificial intelligence for image understanding.⁶⁶

2.5 1985

The “Third International Conference on Picture Archiving and Communication Systems” was chaired by Samuel J. Dwyer III and Robert J. Schneider. At this meeting the ACR-NEMA digital imaging interface standard was first mentioned in two papers.^{67,68} Sam Dwyer presented his seminal work on archival requirements that led to the concept of a hierarchical storage management schema.⁶⁹ Networking,⁷⁰ image data compression,^{71,72} and design considerations for image display^{73-78,78} were topics presented. The importance of inclusion of comparison examinations in PACS displays,⁷⁹ integration of radiology reporting systems,⁸⁰ and integration into clinical workflow,⁸¹ were all mentioned. Examples of PACS at several institutions^{82,83} were described along with cost-benefit implications.⁸⁴ Concepts in perception were also presented.⁸⁵ Also held in Boston, Massachusetts, was a “Medical Imaging and Instrumentation” conference that had papers on DICOM⁸⁶ and on PACS design.⁸⁷ Many papers included medical physics assessments of imaging modalities including computed radiography (CR).

2.6 1986

No specific PACS conference was held in 1986 but the conference on “Physics and Engineering of Computerized Multidimensional Imaging and Processing” was held in Newport Beach, CA. Topics included medical physics of imaging modalities, image reconstruction, image processing, 3D display, and a paper describing the implementation of the AT&T PACS at Duke University Medical Center.⁸⁸

2.7 1987

The first medical imaging titled conference “Medical Imaging I” chaired by Samuel J. Dwyer III and Roger H. Schneider was held in Newport Beach, California, a recurring location for the SPIE Medical Imaging meetings. Papers on digital projection radiography were prominent. Industry researchers including those from Eastman Kodak,⁸⁹ EI du Pont de Nemours,⁹⁰ and Philips Medical Systems⁹¹ described image quality of computed radiography (CR) (with photostimulable storage phosphor detectors), as did academic researchers.^{92,93} Progress for the ACR-NEMA standard was reported,⁹⁴ compression methodologies^{95,96} described, and an algorithm for computerized detection of lung nodules on digital chest radiographs⁹⁷ was presented. Digital image quality assessment and other image processing papers were given.

2.8 1988

SPIE “Medical Imaging II” had the highest number of papers given (188) of any SPIE PACS conference. It was again chaired by Samuel J. Dwyer III and Roger H. Schneider and held in Newport Beach, California. Multiple papers covered image processing and medical physics topics, particularly image quality comparison of screen/film radiography with CR⁹⁸⁻¹⁰² including an ROC (receiver operating characteristic) observer study.¹⁰³ Compression techniques were described,¹⁰⁴⁻¹⁰⁶ and digital workstations with comparison to conventional reading including user interface studies were presented.¹⁰⁷⁻¹¹⁵ Image networking and transmission studies,¹¹⁶⁻¹¹⁸ and PACS technology impact¹¹⁹⁻¹²¹ and cost analyses^{122,123} papers were presented. Multiple

institutions shared their PACS implementation experiences including the University of California at Los Angeles (UCLA), Georgetown University, the University of Pennsylvania, the University of North Carolina at Chapel Hill, Washington University at St. Louis Mallinckrodt Institute, Kyoto University Japan, Victoria Hospital Canada, Toshiba Corporation, and the US Army.¹²⁴⁻¹³⁵ The ACR-NEMA Standard Committee that included representatives from academia and industry (eg, Philips Medical Systems; Picker Medical Systems; NEMA; Siemens Medical Systems, US; New York University; Bio-Imaging Research, Inc.; Reality Technologies; Digital Equipment Corp; Veteran's Administration Medical Center) reported on updates, and implementations using the standard were described.¹³⁶⁻¹⁴⁰ Several papers detailed image archiving,¹⁴¹⁻¹⁴⁶ and two papers discussed the important concept of interfacing hospital information systems and/or radiology operations/information systems with PACS.^{147,148}

2.9 1989

Medical Imaging III first used the conference title "PACS System Design and Evaluation" which was used through 1994. Held in Newport Beach, California, the meeting was chaired by Samuel J. Dwyer III, R. Gilbert Jost, and Roger H. Schneider. Architecture descriptions and PACS evaluation papers dominated the meeting,¹⁴⁹⁻¹⁶⁵ with a few papers covering archives,¹⁶⁶⁻¹⁶⁸ networks¹⁶⁹⁻¹⁷¹ and displays.¹⁷²⁻¹⁷⁵ Multiple papers described radiology information systems (RIS) and their important link to PACS functionality.¹⁷⁶⁻¹⁷⁸ Several papers evaluated cost.¹⁷⁹⁻¹⁸⁴ Figure 1 (bottom) shows the distribution of the sum of topics during the 1980s.

3 1990s PACS Conferences

3.1 1990

"Medical Imaging IV: PACS Systems Design and Evaluation" was chaired by Samuel J. Dwyer III and R. Gilbert Jost and held again in Newport Beach, California. It had the second largest number of papers at 113. Topics covered cost analysis of film versus PACS workflow,¹⁸⁵ time savings¹⁸⁶ and clinical evaluations,^{187,188} including image quality assessments.^{189,190} The notion of multiple types of workstations (diagnostic, clinical review, low-cost) were presented¹⁹¹⁻¹⁹³ as were industry efforts¹⁹⁴ and modality mini-PACS.¹⁹⁵⁻¹⁹⁷ Network performance including experience with wide-area networks¹⁹⁸ were studied,¹⁹⁹⁻²⁰¹ along with archive models.²⁰²⁻²⁰⁵ Interfacing RIS-to-PACS for incorporation of clinical history and comparison images were important topics.²⁰⁶⁻²⁰⁹

3.2 1991

Medical Imaging V: "PACS Design and Evaluation" was chaired by Samuel J. Dwyer III and R. Gilbert Jost and held in San Jose, California. Popular paper topics included the use of PACS as "Teleradiology" within a hospital^{210,211} including industry collaborations²¹² and reports from Europe.^{213,214} High-resolution (2K x 2K) display stations were described including for mammography viewing.^{215,216} Fast networks of the time, including those using the ACR/NEMA standard with TCP/IP over ethernet were detailed.²¹⁷⁻²¹⁹ PACS reliability issues were discussed and reading times on workstations compared with the film alternator.^{220,221} Hospital information system (HIS)-RIS integration with PACS were again a common theme describing image management optimization.²²²⁻²²⁵ Radiologists' opinions on the use of PACS were studied^{226,227} and a paper demonstrating a digital radiologic teaching file was presented.²²⁸

3.3 1992

Medical Imaging VI: "PACS Design and Evaluation" was chaired by R. Gilbert Jost and held in Newport Beach, California. Papers analyzing PACS performance including operations, clinical assessments and user interface optimization at academic hospitals and for military installations were numerous.²²⁹⁻²³⁷ Networks were described including use of a dial-up 56Kbit modem,²³⁸ and high-speed technologies were becoming available.²³⁹⁻²⁴² Description of other

necessary PACS components beyond the display station were presented including embedding PACS databases with HIS/RIS functionality.^{243-246,246} An update on the ACR-NEMA “Digital Imaging and Communications in Medicine” was given²⁴⁷ and data protection and security issues of PACS were discussed.²⁴⁸ The UCLA Laboratory of H.K. Bernie Huang had a large presence accounting for 20% of the papers presented.^{229-231,240,243,245}

3.4 1993

Medical Imaging 1993: “PACS Design and Evaluation” was again chaired by R. Gilbert Jost and held in Newport Beach, California. Studies of network bandwidth,²⁴⁹ high-speed networks,²⁵⁰ archives,²⁵¹ and architectures²⁵² were prevalent. Workstation design including a PC workstation,²⁵³ high-resolution 2K diagnostic workstations²⁵⁴ and display functionality²⁵⁵ were presented, along with PACS evaluation at Hammersmith Hospital.²⁵⁶ There were multiple papers covering standardization in Europe,²⁵⁷ ACR-NEMA²⁵⁸⁻²⁶⁰ and DICOM v3.0,²⁶¹ including a report of the DICOM demonstration at RSNA’s InfoRAD.²⁶² The importance of interfacing PACS with HIS-RIS was again discussed.²⁶³ Multiple papers showcased emerging technologies in videoconferencing for the purposes of expert radiological consultation,^{264,265} teleradiology for the defense medical establishments²⁶⁶ and education.²⁶⁷

3.5 1994

The third highest number of papers (97) were presented at Medical Imaging 1994: “PACS Design and Evaluation” chaired by RG Jost in Newport Beach, California. Teleradiology systems including for pathology images²⁶⁸⁻²⁷⁰ and networking performance including asynchronous transfer mode (ATM) in wide-area networks were reported,^{268,271-273} as was the use of personal computer technology for a radiologic review workstation.²⁷⁴ Again, the importance of interfacing RIS to PACS for enhanced functionality was presented in multiple papers.²⁷⁵⁻²⁷⁷ In particular, several papers discussed archiving and the notion of prefetching relevant prior examinations using the RIS-PACS interface.²⁷⁸⁻²⁸¹ DICOM conformance was reported in a number of papers²⁸²⁻²⁸⁷ as were experiences with modality-specific mini-PACS.²⁸⁸⁻²⁹¹ A multi-hospital European PACS,²⁹² Mayo Clinic,²⁹³ UCSF,²⁹⁴ and the US military²⁹⁵ reviewed PACS clinical implementation statuses. Economic assessment of PACS,²⁹⁶ technology assessment,²⁹⁷ image quality,²⁹⁸ and transitioning from film to digital imaging²⁹⁹ were included topics.

3.6 1995

Medical Imaging 1995 took on a new title “PACS Design and Evaluation: Engineering and Clinical Issues.” R. Gilbert Jost and Samuel J. Dwyer III chaired the conference held for the first time in San Diego, California. Popular topics included DICOM-HL7 interfaces using standards,³⁰⁰⁻³⁰⁵ networking technologies³⁰⁶⁻³⁰⁹ including ATM, T-1 lines and satellite. Teleradiology examples³¹⁰⁻³¹² and radiologists’ technology acceptance³¹³ were shared. Ultrasound³¹⁴ and CT and MR PACS³¹⁵ were described. Experiences with totally digital departments were shared from Europe.^{316,317} Hierarchical storage management design³¹⁸ and fault tolerance for archives³¹⁹ were also topics.

3.7 1996

Medical Imaging 1996 “PACS Design and Evaluation: Engineering and Clinical Issues” was chaired again by R. Gilbert Jost and Samuel J. Dwyer III. It was held in the familiar location of Newport Beach, California. Long-term archive strategies including use of a 3TB jukebox were topics,^{320,321} as were high-performance servers^{322,323} and high bandwidth networks.^{324,325} The DICOM standard,³²⁶⁻³²⁸ use of the World-Wide-Web³²⁹ and RIS-to-PACS integration³³⁰ were popular paper topics. Specialty PACS including those for endoscopy,^{331,332} digital echocardiography,³³³ mammography,³³⁴ and a telemedicine trial to China³³⁵ were described. Lessons learned from large-scale PACS implementations at UCSF,³³⁶ Mayo Clinic Jacksonville³³⁷ and Japan³³⁸ were shared. Direct digital radiography (DR) integration with PACS³³⁹ was described, cost

analysis for film-based versus digital portable chest systems³⁴⁰ was presented, and a clinical comparison of CR versus screen-film for imaging the critically ill neonate³⁴¹ was reported. A study of the impact and utilization of a PACS display in the ICU setting was described³⁴² as well as functional differences between workstations for use by radiologists versus physicians.³⁴³

3.8 1997

Medical Imaging 1997 “PACS Design and Evaluation: Engineering and Clinical Issues” was chaired by Steven C. Horii and G. James Blaine. It was held again in Newport Beach, California. In spite of the excitement for technology advances and anticipation of the benefits of digital imaging and PACS, multiple papers presented a more critical view noting the pitfalls and shortcomings^{344,345} in a session titled “PACS: Why Has It Taken So Long?” One issue was the lack of RIS integration, creating PACS without the intelligence of the traditional film-based workflow.^{346–352} A second issue was the lack of availability of digital images to those needing them outside of radiology.^{353,354} Workstation requirements for very large PACS implementations³⁵⁵ and networking bottlenecks^{356,357} were also problematic. Eliot Siegel, Bruce Reiner, et al. at the Baltimore VA Medical Center described their experience with PACS,³⁵⁸ and multiple experiences with teleradiology were detailed.^{359–364} Archives including tape solutions were covered^{365,366} and data security risks were described.^{367–369} CR image postprocessing,³⁷⁰ CR in the Emergency Department³⁷¹ and digital chest radiography,³⁷² digital mammography³⁷³ and dental images³⁷⁴ were among the applications of digital X-rays. Cost and productivity analyses^{375,376} were presented. Finally, the notion of PACS as an element of the computerized patient record was considered³⁷⁷ foretelling today’s electronic medical records, along with thoughts for “an information revolution in imaging in healthcare.”³⁷⁸

3.9 1998

In 1998 the Medical Imaging “PACS Design and Evaluation: Engineering and Clinical Issues” conference made the near-permanent move to San Diego, California. It was again chaired by Steven C. Horii and G. James Blaine. Prominent papers this year included topics in PACS infrastructure including networks,^{379,380} archives,³⁸¹ security,³⁸² compression,³⁸³ and workstations.³⁸⁴ Teleradiology applications^{385–387} and assessment of PACS across networked sites^{388–390} were described. Non-radiologist clinician image review patterns were studied.³⁹¹ Implementation of an HL7-DICOM broker for automated patient demographic data entry at the image acquisition modality was described³⁹² and the impact of a speech recognition report generation system was reported.³⁹³ At this time some institutions were beginning to undergo major hardware and software upgrades to systems and one such experience was shared.³⁹⁴

3.10 1999

G. James Blaine and Steven C. Horii closed out the century chairing the Medical Imaging 1999 “PACS Design and Evaluation: Engineering and Clinical Issues” conference held in San Diego, California. Multiple papers addressed data security,^{395,396} standards,^{397–399} and PACS quality control⁴⁰⁰ with one paper alerting to the frequency of failure of high resolution monitors used in many thoracic radiology reading rooms.⁴⁰¹ Papers describing network and archival technologies were prominent.^{402–404} JPEG and wavelet compression,⁴⁰⁵ the use of PACS databases for digital atlases,⁴⁰⁶ and post-processing techniques required for optimal display of CR images^{407,408} were presented. Many sites had not yet adopted digital projection radiography so X-ray film digitizers were often required. Laser versus charge-coupled-device (CCD) digitizers were compared in a paper by Gitlin.⁴⁰⁹ Often placement of digital workstations were not optimal having to work around spaces created for analog film display and workflow. Reiner, Siegel, and Rostenberg presented important work in redesigning the reading room for PACS.⁴¹⁰ Along these lines, Horii, Kundel, et al. pointed out the shift in workflow and the consequences of the lack of automation of steps previously handled by radiology film librarians.⁴¹¹ Figure 2 (top) shows the distribution of the sum of topics presented during the 1990s meetings.

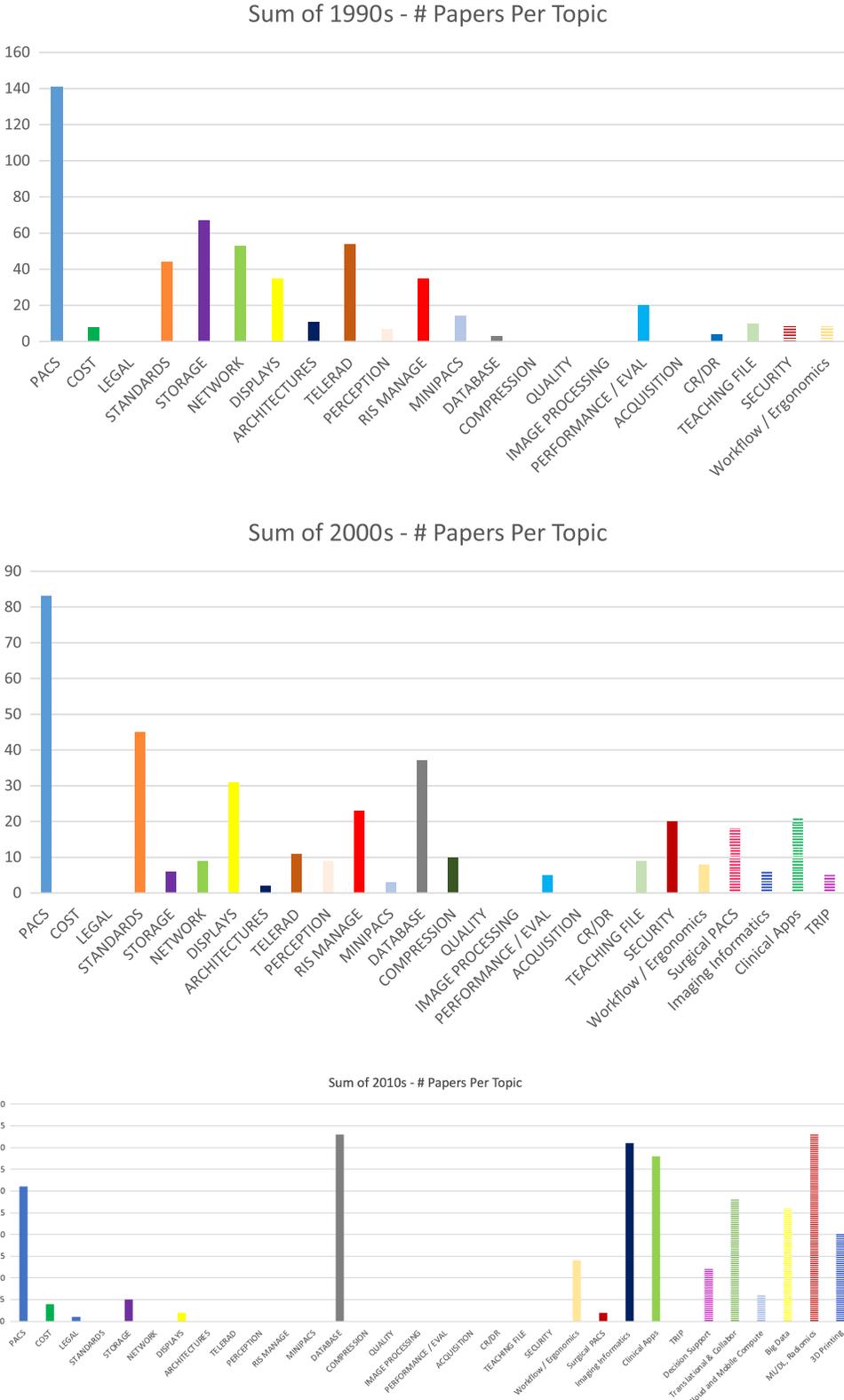


Fig. 2 Distribution of the sum of topics presented during the 1990s meetings (top), 2000s meetings (middle), and 2010s meetings (bottom). The topics to the right with horizontal line fill are new topics to the decade.

4 2000s PACS Conferences

4.1 2000

At the Medical Imaging 2000 “PACS Design and Evaluation: Engineering and Clinical Issues” conference held in San Diego, CA and chaired by G James Blaine and Eliot L. Siegel, several PACS visionaries shared their experiences with PACS development and clinical implementations. These included a history of PACS presented by Samuel J Dwyer III;⁴¹² Heinze Lemke’s look at PACS in Europe;⁴¹³ Guenther Gell’s review of the radiological PACS at the University of Graz, Austria;⁴¹⁴ HK Bernie Huang’s experiences at UCLA and UCSF;⁴¹⁵ Eliot Siegel’s review of PACS adoption at the Department of Veterans Affairs;⁴¹⁶ Anna Chacko’s description of PACS implementation at the Department of Defense;⁴¹⁷ David Channin’s experience with PACS at Northwestern Memorial Hospital;⁴¹⁸ and Hee-Joung Kim’s review of PACS at Yonsei University Colleges of Medicine and Dentistry in Seoul, South Korea.⁴¹⁹ Compression was a big topic as image volume and examination size continued to increase.^{420–424} Implementation of DICOM 3.0⁴²⁵ and moving a live PACS with zero downtime⁴²⁶ were presented.

4.2 2001

For the Medical Imaging 2001 meeting the conference name was changed to “PACS and Integrated Medical Information Systems: Design and Evaluation” to meet the growing realization that PACS without medical information systems was a PACS without knowledge. The meeting was chaired by Eliot L. Siegel and HK Bernie Huang and held in San Diego, California. There continued to be reports of PACS implementations^{427–429} including in China.^{430,431} Digital projection radiography was increasingly being used including CR and DR technologies.^{432,433} Concerns over image display quality were raised as use of digital projection radiography increased^{434,435} and the DICOM committee included an image display consistency test in the standard.⁴³⁶ An additional new DICOM module addressed structured reporting.⁴³⁷ Information security and adhering to HIPAA (Health Insurance Portability and Accountability Act) were discussed.^{438–440} The Integrating the Healthcare Enterprise (IHE) initiative established in 1998 was now being implemented. One of the profiles addressed the difficult management and presentation of grouped procedures.⁴⁴¹ Assessing imaging examination results outside of radiology,⁴⁴² challenges associated with incorporating non radiological images into the EMR,⁴⁴³ and medical-legal issues were discussed.⁴⁴⁴

4.3 2002

The Medical Imaging 2002 “PACS and Integrated Medical Information Systems: Design and Evaluation” conference was chaired by Eliot L. Siegel and HK Bernie Huang and held in San Diego, California. A common theme at this year’s meeting was reliability and monitoring of PACS operations^{445–447} including the problem of imaging examination demographic data error entry at acquisition.⁴⁴⁸ Multiple papers reviewed PACS evolution, industry, status, along with a cost assessment of PACS in Korea.^{449–453} A web-based image archive was described⁴⁵⁴ as an archive upgrade and clinical migration experience,⁴⁵⁵ now becoming necessary as early PACS installations outgrew their storage volumes and technology obsolesced. Financial and workflow analyses⁴⁵⁶ and the difficulty of automating efficient hanging protocols for radiology workstations⁴⁵⁷ were detailed. Standards including the extension of DICOM to other imaging specialties⁴⁵⁸ and the third year of the IHE RSNA demonstration⁴⁵⁹ were presented. Wireless communication at 100 Mbps was explored.⁴⁶⁰

4.4 2003

The Medical Imaging 2003 “PACS and Integrated Medical Information Systems: Design and Evaluation” conference was chaired by HK Bernie Huang and Osman M. Ratib. It was held in San Diego, California for the sixth year in a row. The meeting began with a special opening on the IHE initiative in Europe.⁴⁶¹ Monitoring PACS loading and performance,⁴⁶² tele-imaging over

the international Internet²,⁴⁶³ security,⁴⁶⁴ and DICOM image viewers⁴⁶⁵ were topics covered. A second special session was held on content-based image retrieval.^{466–468} On the display side, compression was used creatively for processing purposes.^{469,470} A database server that enabled more flexible querying of the PACS archive than prior methods was presented.⁴⁷¹ An interesting clinical functionality providing pathology feedback to the radiologist was achieved via monitoring of HL7 feeds.⁴⁷² This value-add capability was not available in any clinical PACS then and few since this initial mention.

4.5 2004

For Medical Imaging 2004 the PACS conference title changed again, this time to “PACS and Imaging Informatics.” It was chaired by Osman M. Ratib and H.K. Bernie Huang and held in San Diego, California. In a special opening session covering a new paradigm in digital image interpretation, Katherine P. Andriole presented “Transforming the Radiological Interpretation Process: The SCAR TRIP Initiative.” Described in the paper by K.P. Andriole, R.L. Morin, et al.,⁴⁷³ the TRIP Initiative aimed to foster inter-disciplinary research on technological, environmental, and human factors to better manage and exploit the massive amounts of data being produced in medical imaging. With goals to improve the efficiency of interpretation of large data sets, improve the timeliness and effectiveness of communication, and decrease medical errors, ultimately improving the quality and safety of patient care, a call was made for interdisciplinary research into several broad areas: human perception, image processing and computer-aided detection (CAD), visualization, navigation and usability, databases and integration, and evaluation and validation of methods and performance. Standards were reviewed in several papers^{474,475} along with a discussion of the effect of viewing angle response on DICOM-compliant liquid crystal displays.⁴⁷⁶ Compression strategies,⁴⁷⁷ content-based image retrieval for cell pathology,⁴⁷⁸ a web viewer for cardiac images,⁴⁷⁹ and study of human perception and ergonomics to improve workstation user productivity⁴⁸⁰ were among the other interesting topics.

4.6 2005

Medical Imaging 2005 “PACS and Imaging Informatics” held in San Diego, California, was chaired by Osman M. Ratib and Steven C Horii. A special opening session covered new trends in PACS including reflections on technology adoption,⁴⁸¹ software strategies,⁴⁸² and navigation of large datasets.^{483–486} The “Operating Room of the Future” was the topic in a special joint session of SPIE and the Computer Assisted Radiology and Surgery (CARS) meetings with representative papers covering workflow.^{487,488} Observer performance papers addressed image quality and monitor display settings.^{489,490} Image compression methodologies,^{491,492} grid-computing for multi-dimensional image rendering,⁴⁹³ thin client architecture for image analysis,⁴⁹⁴ and security algorithms⁴⁹⁵ were among the topics covered.

4.7 2006

Medical Imaging 2006 “PACS and Imaging Informatics” was again held in San Diego, California, and chaired by Steven C. Horii and Osman M. Ratib. Fewer papers were presented at the PACS meeting than previously, as SPIE Medical Imaging specialty conferences split off into their own parallel tracks. Several papers explored display topics optimizing reading room ambient lighting,⁴⁹⁶ to on-demand rendering of oblique slices through 3D volumes⁴⁹⁷ – something not native to most PACS displays at the time. As imaging examination data continued to grow, the impact on archives was a topic of interest^{498,499} as was compression.⁵⁰⁰ Interventional radiology and surgical workflows were discussed.^{501–503} Standards papers were prominent including approaches for structured reporting,⁵⁰⁴ DICOM-RT for radiation therapy,⁵⁰⁵ and document sharing with the IHE cross-enterprise document sharing profile (XDS).^{506,507} The notion of sharing medical images in a reference database⁵⁰⁸ was proposed perhaps foreshadowing the need we have today for data sharing for developing generalizable machine learning models.

4.8 2007

Medical Imaging 2007 “PACS and Imaging Informatics” marked the 25th year of PACS conferences. The meeting was again held in San Diego, California, and chaired by Steven C. Horii and Katherine P. Andriole. Papers on solutions for the digital surgical operating room,⁵⁰⁹ therapy,⁵¹⁰ and DICOM for surgery⁵¹¹ were presented. A grid-based implementation of XDS was presented as part of a metropolitan electronic health record in Shanghai.⁵¹² Papers described digital pathology applications and examined the impact of incorporating whole-slide imaging in PACS archives.⁵¹³ The quality of image displays was discussed including high-resolution⁵¹⁴ and color monitors,^{515,516} mobile display systems,⁵¹⁷ as well as the impact of ambient lighting on detectability of findings.⁵¹⁸ The variability in automated analysis tools for volumetric measurements⁵¹⁹ was presented, as was a toolkit for integrating independent computer-aided detection (CAD) workstations to the diagnostic workflow⁵²⁰ since most CAD applications at the time were accessible only on stand-alone workstations. A report on the gaps in content-based image retrieval⁵²¹ was given, and several papers addressed the use of the now-digital imaging treasure troves of data in PACS for research purposes.⁵²²⁻⁵²⁴ An interesting observer study was performed using 3D surface reconstructed CT facial images to ascertain whether viewers could identify individual patients.⁵²⁵

4.9 2008

The Medical Imaging 2008 “PACS and Imaging Informatics” meeting chaired by Katherine P. Andriole and Khan M. Siddiqui opened with a moment of silence to mark the passing of Samuel J. Dwyer III, affectionately known as “The Father of PACS” (Fig. 3). Dr. Dwyer chaired the second international PACS meeting and eight subsequent conferences. Among the many tributes, Sam was called “a leading light in the swift growth of the field of medical imaging; a leading force in the development of this new science and technology as the conferences developed and grew; he had an ability to predict important technology trends in medical imaging; one of the first to envision the impact of digital technology on the storage, retrieval, communication, and display of medical images, and one of the most active early explorers of the possibilities; a true pioneer in our field.”⁵²⁶

Decision support tools and CAD were topics of interest.⁵²⁷⁻⁵²⁹ PACS in other specialties and locations including the intensive care unit,⁵³⁰ and the operating room⁵³¹⁻⁵³³ were detailed. Standards including health level 7 (HL7) for text exchange,⁵³⁴ DICOM displays⁵³⁵ and DICOM



Fig. 3 Samuel J. Dwyer III (1932 – 2008) – “The Father of PACS.”

structured reporting (SR)⁵³⁶ were topics. Multiple studies examined display image quality including improved calibration for viewing angle to adjust for the narrow angle-of-regard limitation of early liquid crystal displays (LCDs),⁵³⁷ grayscale and luminance adjustability,⁵³⁸ and attention to ambient lighting and its impact on detection accuracy.⁵³⁹ HIPAA compliance and signature embedding⁵⁴⁰ was a topic. More papers covered research uses of PACS and the ability to query the RIS and PACS databases.⁵⁴¹ Several papers examined the use of texture and shape analyses.^{542,543}

4.10 2009

A new name was used to close out the decade: Medical Imaging 2009 “Advanced PACS-Based Imaging Informatics and Therapeutic Applications.” Chaired by Khan M. Siddiqui and Brent J. Liu, the location also changed to Lake Buena Vista, Florida. In keeping with the name change, multiple papers described specialty clinical applications including for spine surgery,⁵⁴⁴ endoscopy,⁵⁴⁵ multiple sclerosis treatment,⁵⁴⁶ breast cancer,⁵⁴⁷ stroke,⁵⁴⁸ telemedicine,⁵⁴⁹ and regional healthcare.⁵⁵⁰ Research databases^{551,552} and CBIR^{553,554} were also topics of interest. Papers on healthcare interoperability⁵⁵⁵ and digital archives^{556,557} were presented. Tools for moving image processing research to the clinical environment were discussed in a paper from Ronald Summers’ laboratory.⁵⁵⁸ Figure 2 (middle) shows the distribution of the sum of topics presented during the 2000s meetings.

5 2010s PACS Conferences

5.1 2010

Medical Imaging 2010 “Advanced PACS-Based Imaging Informatics and Therapeutic Applications” was held in San Diego, California, and chaired by Brent J. Liu and William W. Boonn. Standard topics with a new approach were presented including automated text detection on images for de-identification of pixel data in compliance with HIPAA,⁵⁵⁹ and DICOM structured reporting⁵⁶⁰ and image transmission.⁵⁶¹ Report indexing and search⁵⁶² and semantic annotation of images⁵⁶³ were presented. A zero-footprint 3D visualization system⁵⁶⁴ was described in contrast to the stand-alone advanced post-processing systems of prior years, and an update on TRIP⁵⁶⁵ was given. Development of an automated tracking system for radiology feedback and incidental finding follow-up was presented,⁵⁶⁶ and the first SPIE Medical Imaging meeting mention of the use of a GPU was given in a paper evaluating volumetric segmentation of multiple sclerosis lesions.⁵⁶⁷

5.2 2011

Medical Imaging 2011 “Advanced PACS-Based Imaging Informatics and Therapeutic Applications” was held in Lake Buena Vista, Florida in the alternating location format and chaired by William W. Boonn and Brent J. Liu. Multiple papers explored radiology reporting including the Breast Imaging-Reporting and Data System (BI-RADS) structured format and follow-up,⁵⁶⁸ DICOM structured reporting (SR) of organ radiation dose,⁵⁶⁹ automated detection of adrenal findings as documented in reports,⁵⁷⁰ database searches for uncovering radiology billing and coding errors,⁵⁷¹ and multimedia electronic patient records.⁵⁷² Use of GPU computing⁵⁷³ and web-based image transmission and display⁵⁷⁴ were again topics of interest. IHE for surgery⁵⁷⁵ was discussed, and comparison of 2D versus 3D mammography acquisition and display devices were examined via an observer study.⁵⁷⁶

5.3 2012

Medical Imaging 2012 marked thirty years of PACS meetings. It kept the previous year’s title “Advanced PACS-Based Imaging Informatics and Therapeutic Applications” and went back to San Diego, California. The conference was again chaired by William W. Boonn and Brent J. Liu.

Cloud-based storage of medical images was mentioned for the first time,⁵⁷⁷ and display of images on a small-footprint iPad device was discussed.⁵⁷⁸ Report annotation,⁵⁷⁹ image retrieval,⁵⁸⁰ and data mining of DICOM-RT (radiation therapy) objects were presented.⁵⁸¹ The value of digital stores of images and relevant information was being utilized for CAD systems.^{582,583}

5.4 2013

Medical Imaging 2013 “Advanced PACS-Based Imaging Informatics and Therapeutic Applications” was back in Lake Buena Vista, Florida. The meeting was chaired by Maria Y. Law and William W. Boonn. Topics covered included CAD,⁵⁸⁴ teleradiology with secure cloud storage,⁵⁸⁵ enhancements to the continually evolving DICOM standard including series transmission,⁵⁸⁶ and integration of PACS and CAD systems.⁵⁸⁷ Open-source research PACS including XNAT,⁵⁸⁸ and MIRC-compliant (Medical Imaging Resource Center) digital radiology teaching files⁵⁸⁹ were presented. Infrastructure for the digital operating room⁵⁹⁰ was discussed.

5.5 2014

Medical Imaging 2014 changed titles to “PACS and Imaging Informatics: Next Generation and Innovations.” The meeting chaired by Maria Y. Law and Tessa S. Cook was held back in San Diego, CA. An interesting collection of topics presented included a remote volume rendering pipeline,⁵⁹¹ integration of medical images into a mobile device for bedside viewing,⁵⁹² and medical imaging document sharing using the IHE XDS profile.⁵⁹³ Research data collections⁵⁹⁴ and collaborative frameworks for data mining⁵⁹⁵ were presented. Incorporating intelligence into structured radiology reports⁵⁹⁶ was a paper of interest.

5.6 2015

Medical Imaging 2015 “PACS and Imaging Informatics: Next Generation and Innovations” was chaired by Tessa S. Cook and Jianguo Zhang. It was held in Orlando, Florida. “Big Data” and how to manage and exploit it was presented in multiple papers.⁵⁹⁷⁻⁶⁰¹ Future trends and next generation PACS were discussed,^{602,603} including pathology PACS.^{604,605} A paper including quantitative imaging features and extending a medical imaging database to oncology⁶⁰⁶ was given. Ingesting outside imaging examinations was also a topic.⁶⁰⁷ Monitoring radiation dose⁶⁰⁸ continued to be of interest.

5.7 2016

Medical Imaging 2016 “PACS and Imaging Informatics: Next Generation and Innovations” was chaired by Jianguo Zhang and Tessa S. Cook and held in San Diego, CA. Radiomics was the topic of several papers for classification of breast cancer⁶⁰⁹ and lung nodules.⁶¹⁰ 3D printing for cardiac procedure planning was a topic,⁶¹¹ as was smartphone use for clinical trials.⁶¹² Clinical decision support tools were presented^{613,614} and high performance computing for medical image processing using Amazon web services was assessed.⁶¹⁵ Deep learning and the combination of human and machine intelligence was explored in multiple papers.⁶¹⁶⁻⁶¹⁸

5.8 2017

Medical Imaging 2017 marked the final name change to date: “Imaging Informatics for Healthcare, Research and Applications.” The meeting was held in Orlando, Florida and chaired by Tessa S. Cook and Jianguo Zhang. Image quantification, classification and analysis using radiomics, and convolutional neural networks (CNN) of machine and deep learning were dominant topics.⁶¹⁹⁻⁶²³ 3D printing papers were presented,^{624,625} as were clinical decision support applications to reduce radiation dose.⁶²⁶ Mobile devices were described for 3D wound care⁶²⁷ and DICOM was still a topic at the meeting, this time for image quantification secondary capture.⁶²⁸

5.9 2018

Medical Imaging 2018 “Imaging Informatics for Healthcare, Research and Applications” was held in Houston, Texas, for the first time. It was chaired by Jianguo Zhang and Po-Hao Chen. The meeting opened with a debate between Bradley J. Erickson and Eliot L. Siegel on “Will Computers Replace Radiologists for Primary Reads in 20 Years?,”⁶²⁹ and an introduction of H.K. Bernie Huang’s textbook *PACS-Based Multimedia Imaging Informatics* 3rd Edition.⁶³⁰ Papers covered histopathology whole-slide image and genomic data,⁶³¹ crowd-sourced image annotation⁶³² and many presentations on machine learning.^{633–639} 3D printing was also of interest.⁶⁴⁰

5.10 2019

Medical Imaging 2019 “Imaging Informatics for Healthcare, Research and Applications” was held in San Diego, California, and chaired by Po-Hao Chen and Peter R. Bak. The dominating paper topic was deep learning with multiple applications including classification of thoracic radiographs,⁶⁴¹ breast tumor segmentation,⁶⁴² optic disc segmentation in fundus images,⁶⁴³ molecular subtype prediction in glioblastoma multiforme,⁶⁴⁴ and vertebrae segmentation on CT images.⁶⁴⁵ Newer machine learning architectural approaches were presented including generative adversarial networks (GANs) applied to electronic cleansing on CT colonography⁶⁴⁶ and breast cancer detection,⁶⁴⁷ and a long-short-term memory (LSTM) model was used for sequence labeling in clinical reports.⁶⁴⁸ Papers on 3D printing were also presented.^{649–651} Figure 2 (bottom) shows the distribution of the sum of topics presented during the 2010’s meetings as they have evolved from the 1990s and the 2000s.

6 2020s PACS Conferences

6.1 2020

Medical Imaging 2020 “Imaging Informatics for Healthcare, Research and Applications” was held in Houston, Texas, and chaired by Po-Hao Chen and Thomas M. Deserno. While papers were included on a new generation of PACS based on artificial intelligence,⁶⁵² cloud platforms for CAD and collaboration,⁶⁵³ and 3D printing,⁶⁵⁴ the overwhelming number of papers presented were on deep learning,^{655–661} including some novel architectures: unsupervised learning,⁶⁶² 3D attention U-Net,⁶⁶³ and GANs.⁶⁶⁴

6.2 2021

Due to the COVID-19 pandemic, Medical Imaging 2021 “Imaging Informatics for Healthcare, Research and Applications” was held virtually online. The conference was chaired by Thomas M. Deserno and Brian J. Park. Understandably, several papers described applications to aid in the management of patients with COVID.^{665–667} Unsupervised⁶⁶⁸ deep learning, LSTM architectures,⁶⁶⁹ and GANs⁶⁷⁰ were again popular paper topics. Challenges with privacy risks in deep learning models were described.⁶⁷¹ Handheld device displays,⁶⁷² 3D printing challenges,⁶⁷³ and integrated PACS workflow⁶⁷⁴ were also presented.

6.3 2022

Medical Imaging 2022 “Imaging Informatics for Healthcare, Research and Applications” was held back in San Diego, California, and again chaired by Thomas M. Deserno and Brian J. Park. The radiology reading room in the era of COVID-19 was described,⁶⁷⁵ operating room workflow analysis,⁶⁷⁶ and image de-identification using cloud services.⁶⁷⁷ As in recent years, the bulk of papers presented explored topics in machine learning including federating learning approaches,^{678,679} CNNs for respiratory disease management,^{680,681} uncertainty quantification in deep learning,⁶⁸² encoder-decoder architectures,⁶⁸³ and clinical implementation of deep learning applications into the radiology workflow.⁶⁸⁴

7 Conclusion

In total, 2,428 papers have been presented through the 40 years of SPIE PACS conferences. The conference has undergone eight name changes. The most frequent meeting locations were San Diego, California, eighteen times; Newport Beach, California, eleven times; and the Orlando area of Florida five times. Several conference chairs/co-chairs served multiple times including Sam Dwyer the most at nine conference chairs, Gil Jost at eight, Steve Horii at six, and H.K. Bernie Huang served five times.

The first PACS conferences covered the concept of image management systems/PACS, its infrastructure and components for image acquisition, network transmission, storage devices, display workstations, and architectures. Image processing, digital projection radiography (CR/DR), and early ACR-NEMA standards were also discussed. Key researchers of the decade were: Andre J. Duerinckx (Philips Ultrasound, Inc), Samuel J Dwyer III (University of Kansas and University of Virginia), R. Gilbert Jost and G. James Blaine (University of Washington, St Louis, Mallinckrodt Institute), Steven C. Horii (NYU, Georgetown and University of Pennsylvania), Ronald L. Arenson (University of Pennsylvania and UCSF), and H.K. Bernie Huang (UCLA and UCSF). Many industry researchers presented their work.

In the 1990s many of the same topics were covered with a focus on systems implementations, advances in networks, teleradiology, standards now evolving to DICOM, and display workstations by functionality (radiologist diagnostic versus clinician review). Security and ergonomics and workflow appeared as paper topics of interest. CR/DR advances were covered in the Medical Physics conference. H.K. Bernie Huang's laboratories at UCLA and subsequently UCSF were major contributors along with R.G. Jost, G.J. Blaine (University of Washington), Janice Honeyman-Buck, Edward V. Staab and M.M. Frost (University of Florida), S.K. Mun (Georgetown), S.C. Horii, R.L. Arenson and S.B. Seshadri (University of Pennsylvania), and S.J. Dwyer III (University of Virginia).

In the 2000s many PACS implementations and lessons learned were described including US military installations and many international examples. Clinical applications in radiology, radiation therapy, pathology, and surgery were presented along with the research benefits of digital data for content based image retrieval, image processing and analysis, and radiology teaching files. Imaging informatics concepts became fundamentals to medical imaging including standards, security, database management, architectures, display technologies and perception. H.K. Bernie Huang's (UCSF) and Eliot Siegel's (University of Maryland) laboratories were main contributors to the SPIE Medical Imaging conferences during this time.

From 2010-2019 major topics included imaging informatics concepts, clinical PACS examples, intelligent databases and data mining, efficient radiology workflow, and clinical applications. New topics appeared including decision support, cloud archives and cloud computing, big data uses and research collaborations, and 3D printing applications. Many machine and deep learning and radiomics papers were presented. Brent J. Liu's laboratory from the University of Southern California produced many papers on a variety of topics.

So far in the 2020s, machine and deep learning applications continue to be of interest and are covering more nuanced concepts including advanced architectures (GANs, LSTMs), multimodal and unsupervised deep learning, cloud computing, and federated learning. Concerns around data security and patient privacy, bias and uncertainty metrics have also been described. It will be exciting to see what the future SPIE Medical Imaging PACS conferences will bring forward as new technologies, approaches and clinical applications.

Disclosures

No conflicts of interest are declared by the author.

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