# Brief history of Image Processing at SPIE Medical Imaging

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**Abstract.** Image processing has contributed greatly to the clinical applications of medical imaging. Many of the major developments have been stimulated by and reported at the Image Processing (IP) conference held annually as part of the SPIE Medical Imaging meeting. The evolution, focus, and impact of the IP conference is reviewed.  [DOI: 10.1117/1.JMI.9.S1.S12209]

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## 1 Background

Medical Image Processing (IP) at SPIE has a history that begins in the earliest days of the SPIE conference series. It goes back to at least 1971, when a conference entitled "Quantitative Imagery in the Biomedical Sciences" was held and was memorialized in Volume 26 of what became known as the "Yellow Book" series, which comprised the proceedings of all SPIE conferences. (The 2022 IP proceedings, no longer a physical Yellow Book, is Volume 12032!) Although it was not specifically focused on IP, the 1971 conference did include relevant papers, including "An Interactive Image Analyzing System for Bio-Medicine" and "Radiological Imagery Enhancement," along with others on physics, perception, and diagnosis—topics that look familiar today. Subsequent conferences (1974 to 1986; see Appendix A) that dealt with medical topics (instrumentation, picture archiving and communication systems [PACS], clinical applications) had some IP papers, but there was not a broad approach to the overall area. The interested reader can explore further, using the Volume numbers, in the SPIE Digital Library.

## 2 Progress

Then things began to change. In 1987 SPIE held the first Medical Imaging conference (organized by Sam Dwyer), followed in 1988 by Medical Imaging II (organized by Roger Schneider). The meetings had totals of 61 and 196 papers, respectively, spanning the breadth of medical imaging, and including more IP and the beginnings of specialization. The field was increasingly attracting the attention of industry, government, and academia, and in 1989 Medical Imaging III was organized into four conferences: IP, Image Formation, Image Capture and Display, and PACS System Design and Evaluation. That first IP-specific conference included 72 papers; the main topics were segmentation, restoration, classification, modeling, and reconstruction.

The IP conference has flourished ever since. Attendance and the program committee have grown greatly, with both groups increasingly representing the strong international interest in the field. (Appendix B lists the organizers/editors, and Appendix C lists the IP conference titles, years, and Volume numbers of the proceedings.) From the beginning, the meetings have been notable for their collaborative mix of contributors and attendees from government, industry, and academia: clinicians, engineers, mathematicians, policymakers, and others. Figure 1 presents the annual number of papers in the IP conference. The fluctuations include some natural variation, but also two systematic effects: the creation of new conferences that deal with topics that previously were incorporated into IP and now have moved out, and the varying number of days allocated to the IP track at the meeting each year.

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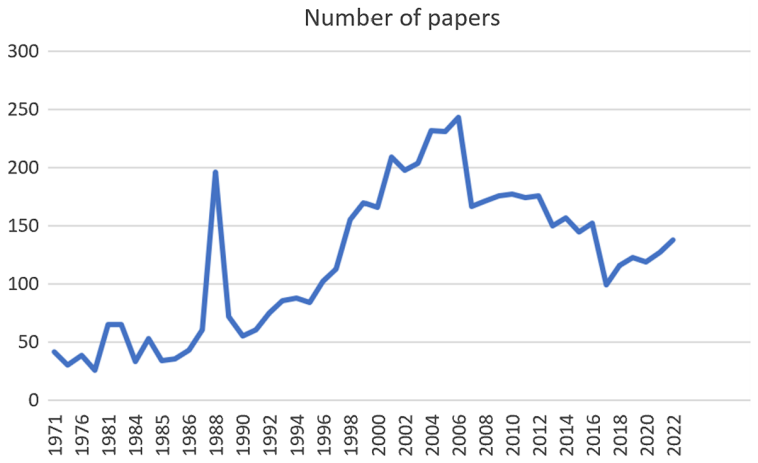


**Fig. 1** Number of Image Processing papers since 1971.

Below are listed the years in which topics that overlap with IP first had their own conferences (post-'89). Note that some of the topics' titles have evolved in the years since their introduction, but the basic themes have been preserved and extended. The introduction of those new conferences clearly had an effect on the content and size of the IP conferences, as seen in Fig. 1.

Medical Imaging 1994: Physiology and function from multidimensional images
Medical Imaging 1995: Image perception
Medical Imaging 2000: Ultrasonic imaging and signal processing
Medical Imaging 2007: Computer-aided diagnosis
Medical Imaging 2013: Digital pathology
Medical Imaging 2014: Image-guided procedures, robotic interventions, and modeling
Medical Imaging 2020: Imaging informatics for healthcare, research, and applications

## 3 The more things change...

As noted above, the creation of new conferences has affected the number and variety of submissions to the IP conference over its history. Other major influences were the introduction of new imaging modalities, the greatly increased computing power available to nearly everyone, widespread use of the Internet, and the concomitant creation and availability of large databases of medical images and of open-source software.

But when we look at the topics of the papers, we find some unchanging strong themes: segmentation, reconstruction, enhancement, registration, diagnosis, and classification. Table 1 shows, for each decade, the number of papers that mentioned a given topic and the number of papers including that topic as a keyword. Because some papers mention a topic only in passing, the keyword measure is likely to be more representative of actual focus. The list is ordered by total keyword count. The increase of interest in artificial intelligence (AI)- and machine learning (ML)-related methods is evident. But they are largely in the service of the perennial topics, which have benefited from—but obviously not been "solved" by—the new technologies, data, and analytic methods. As we have found successes, for example with difficult segmentation problems using AI and ML, we have challenged ourselves with ever more difficult ones.

## 4 Impact

An important measure of the impact of a paper is the number of times it has been cited by others. A search by Lens.org tabulated the top-20 papers from all the SPIE Medical Imaging conferences, per decade. In the decade from 1980 to 1989 (note that IP began in 1989), IP papers appeared seven times (range: 107–24 citations). The next two decades' IP representations were six (1990 to 1999; range: 185-58) and zero (2000 to 2009). More recently (2017 to 2022),

**Table 1** Numbers of IP papers per decade that mentioned ("all") a given topic, and the subset that used the corresponding keyword ("kw").

| | 1981 to 1990 | | 1991 to 2000 | | 2001 to 2010 | | 2011 to 2021 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Topic | all | kw | all | kw | all | kw | all | kw | all | kw |
| Segmentation | 64 | 44 | 731 | 530 | 1660 | 1232 | 1191 | 899 | 3636 | 2705 |
| Registration | 13 | 5 | 281 | 148 | 880 | 511 | 733 | 370 | 1907 | 1034 |
| Diagnosis | 29 | 7 | 449 | 145 | 918 | 295 | 507 | 36 | 1903 | 483 |
| Reconstruction | 47 | 24 | 435 | 121 | 960 | 182 | 563 | 66 | 2005 | 393 |
| Classification | 30 | 7 | 385 | 78 | 758 | 138 | 546 | 82 | 1719 | 305 |
| Enhancement | 58 | 15 | 438 | 94 | 870 | 86 | 591 | 84 | 1957 | 269 |
| NNs or CNNs | 2 | 2 | 35 | 9 | 34 | 8 | 301 | 118 | 372 | 137 |
| Machine learning | 3 | 0 | 42 | 0 | 138 | 26 | 356 | 108 | 539 | 134 |
| Compression | 14 | 7 | 151 | 33 | 357 | 54 | 156 | 25 | 678 | 119 |
| Deep learning | 0 | 0 | 7 | 0 | 18 | 0 | 365 | 24 | 390 | 24 |
| Artificial intelligence | 7 | 1 | 41 | 5 | 55 | 5 | 42 | 11 | 145 | 22 |

and calculated differently, nine IP papers had more than 20 citations each, with the most-cited having 70.

Another measure of impact is the number of downloads of a paper from the SPIE Digital Library. Arbitrarily setting 500 as a minimum, we find that there are 97 papers from all the Medical Imaging conferences that have at least that number. Twenty-two of those are from the Image Processing conference. The second highest overall number of downloads (2528) is an IP paper, "Unsupervised learning-based deformable registration of temporal chest radiographs to detect interval change" (Q. Fang, et al., 2020).

## 5 Conclusions and Outlook

The contributions of image processing to the development and clinical applications of medical imaging are highly significant and almost innumerable. This brief review cannot list the variety and combinations of imaging techniques, analysis and display methods, tools for decision-making, and the ever-increasing array of AI and ML algorithms. Nor can it describe the great breadth of approval and adoption of those advances by government and industry, all to the benefit of patients worldwide.

The people who made all of this happen are also far too numerous to name here. Many names appear repeatedly over several years as authors of papers in specific areas, indicating the dedication, imagination, and perseverance of the leaders in this field. The program committees have always been forward-looking and innovative in the organization of the conferences, with workshops, keynote speakers, challenges, and special programs that motivated us to explore new ideas.

The research areas have had essentially the same names throughout, but the increasing sophistication and application of the work presented in those areas makes clear that the substantial achievements to-date are but prologue to a stimulating and rewarding future for MI and IP at SPIE.

## 6 Appendix A

Table 2 lists the early conferences with IP content.

**Table 2** Early conferences with IP content.

| | |
|---|---|
| Quantitative Imagery in the Biomedical Sciences I | 1971 |
| Medical X-Ray Photo-Optical Systems Evaluation | 1974 |
| Cardiovascular Imaging and Image Processing: Theory and Practice | 1976 |
| Noninvasive Cardiovascular Measurements | 1979 |
| Digital Radiography | 1981 |
| Medical Images and Icons | 1984 |
| Medical Imaging and Instrumentation ′84 | 1984 |
| Application of Optical Instrumentation in Medicine XIII | 1985 |
| Third International Conference on Picture Archiving and Communication Systems | 1985 |
| Medical Imaging and Instrumentation ′85 | 1985 |
| Physics and Engineering of Computerized Multidimensional Imaging and Processing | 1986 |

## 7 Appendix B

Table 3 lists the editors of the IP-related SPIE Proceedings.

**Table 3** Editors of the IP-related SPIE Proceedings.

| | |
|---|---|
| Pre-*Medical Imaging* | |
| 1971 | Herron, Robin, Bayer College of Medicine |
| 1974 | Goodenough, David, Johns Hopkins Medical Institution |
| 1976, 1979 | Harrison, Donald, Stanford Univ. |
| 1981 | Brody, William, Stanford Univ. |
| 1984 | Duerinckx, Andre, Philips Medical Systems |
| 1984, 1985 | Mulvaney, James, Univ. of Michigan |
| 1985 (2) | Dwyer, Samuel, Univ. of Kansas Medical Ctr. |
| 1986 | Budinger, Thomas, Univ. of California/Berkeley |
| Start of *Medical Imaging* | |
| 1987, 1989 | Dwyer, Samuel, Univ. of Kansas Medical Ctr. |
| 1988 | Schneider, Roger, U.S. Food and Drug Administration |
| 1990-1996 | Loew, Murray, George Washington Univ. |
| 1997-2000 | Hanson, Kenneth, Los Alamos National Lab. |
| 2001-2003 | Sonka, Milan, Univ. of Iowa |
| 2004-2005 | Fitzpatrick, J. Michael, Vanderbilt Univ. |
| 2006, 2008 | Reinhardt, Joseph, Univ. of Iowa |
| 2007, 2009 | Pluim, Josien, Univ. Medical Ctr. Utrecht |
| 2010-2011 | Dawant, Benoit, Vanderbilt Univ. |
| 2012 | Haynor, David, Univ. of Washington |
| 2013-2015 | Ourselin, Sébastien, Univ. College London |
| 2016-2017 | Styner, Martin A., The Univ. of North Carolina at Chapel Hill |
| 2018-2019 | Angelini, Elsa D., Imperial College London |
| 2020-2022 | Išgum, Ivana, Amsterdam UMC |

## 8 Appendix C

Table 4 lists the volume numbers of IP conferences.

**Table 4** Volume numbers of IP conferences.

| | | |
|---|---|---|
| 0767 | Medical Imaging | 1987 |
| 0914 | Medical Imaging II | 1988 |
| 1092 | Medical Imaging III: Image Processing | 1989 |
| 1233 | Medical Imaging IV: Image Processing | 1990 |
| 1445 | Medical Imaging V: Image Processing | 1991 |
| 1652 | Medical Imaging VI: Image Processing | 1992 |
| 1898 | Medical Imaging 1993: Image Processing | 1993 |
| 2167 | Medical Imaging 1994: Image Processing | 1994 |
| 2434 | Medical Imaging 1995: Image Processing | 1995 |
| 2710 | Medical Imaging 1996: Image Processing | 1996 |
| 3034 | Medical Imaging 1997: Image Processing | 1997 |
| 3338 | Medical Imaging 1998: Image Processing | 1998 |
| 3661 | Medical Imaging 1999: Image Processing | 1999 |
| 3979 | Medical Imaging 2000: Image Processing | 2000 |
| 4322 | Medical Imaging 2001: Image Processing | 2001 |
| 4684 | Medical Imaging 2002: Image Processing | 2002 |
| 5032 | Medical Imaging 2003: Image Processing | 2003 |
| 5370 | Medical Imaging 2004: Image Processing | 2004 |
| 5747 | Medical Imaging 2005: Image Processing | 2005 |
| 6144 | Medical Imaging 2006: Image Processing | 2006 |
| 6512 | Medical Imaging 2007: Image Processing | 2007 |
| 6914 | Medical Imaging 2008: Image Processing | 2008 |
| 7259 | Medical Imaging 2009: Image Processing | 2009 |
| 7623 | Medical Imaging 2010: Image Processing | 2010 |
| 7962 | Medical Imaging 2011: Image Processing | 2011 |
| 8314 | Medical Imaging 2012: Image Processing | 2012 |
| 8669 | Medical Imaging 2013: Image Processing | 2013 |
| 9034 | Medical Imaging 2014: Image Processing | 2014 |
| 9413 | Medical Imaging 2015: Image Processing | 2015 |
| 9784 | Medical Imaging 2016: Image Processing | 2016 |
| 10133 | Medical Imaging 2017: Image Processing | 2017 |
| 10574 | Medical Imaging 2018: Image Processing | 2018 |
| 10949 | Medical Imaging 2019: Image Processing | 2019 |
| 11313 | Medical Imaging 2020: Image Processing | 2020 |
| 11596 | Medical Imaging 2021: Image Processing | 2021 |
| 12032 | Medical Imaging 2022: Image Processing | 2022 |

## Disclosures

No conflicts of interest, financial or otherwise, are declared by the authors.

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