

# Fifty years of SPIE Medical Imaging proceedings papers

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## Abstract

**Purpose:** To commemorate the 50th anniversary of the first SPIE Medical Imaging meeting, we highlight some of the important publications published in the conference proceedings.

**Approach:** We determined the top cited and downloaded papers. We also asked members of the editorial board of the *Journal of Medical Imaging* to select their favorite papers.

**Results:** There was very little overlap between the three methods of highlighting papers. The downloads were mostly recent papers, whereas the favorite papers were mostly older papers.

**Conclusions:** The three different methods combined provide an overview of the highlights of the papers published in the SPIE Medical Imaging conference proceedings over the last 50 years.

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## 1 Introduction

The SPIE seminar “Application of Optical Instrumentation in Medicine” was held in Chicago on November 29 and 30, 1972. This was the first meeting of what is now known as the

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SPIE Medical Imaging conference. Milestones are important to mark as they are an opportunity to reflect on what has transpired and where we are going. This contribution will highlight some of the important papers published in the conference proceedings.

## 2 Methods

We first looked at common metrics such as citations and downloads, which are reported here. We used Lens.org to create the citation lists. It is worth noting that Lens.org, in general, produces fewer citation numbers than a Google search. The download count was taken directly from the SPIE website.

It is not uncommon for a conference paper to be converted to peer-reviewed publication by the authors. So, although the conference paper and the corresponding presentation may have had significance to the field, it is likely that the citations and downloads were for the peer-reviewed versions.

Given this problem, we chose a different tack, albeit one that is very subjective. We asked members of the current *Journal of Medical Imaging* (JMI) editorial board to write about their favorite SPIE conference paper, and those are also given here. The advantage of asking board members is that, collectively, their expertise spans the subjects presented at Medical Imaging, so it is likely more representative of topics covered.

## 3 Results

### 3.1 Citations

Table 1 gives the top 10 conference proceeding papers (across all symposia) cited by decade. As the size and reputation of the SPIE Medical Imaging conference grew, it became more likely that a paper presented at the conference would be cited, and recent papers have fewer citations because they have had less time to be cited compared with older papers.

The highest cited paper was by Cruz-Roa and colleagues, published in 2014, with 216 citations. It was also selected as a “favorite” paper (see next section). The second highest cited paper was by Bunch et al., with 199 citations. This paper describes a method to quantify the area under the free-response operator characteristic curve, and it was a seminal paper in the field. Despite that it was presented in 1977, it is highly cited due in large part to there being no subsequent peer-reviewed publication.

### 3.2 Downloads

Table 2 lists the top 50 downloaded papers from the conference proceedings. Since downloading from the SPIE website is relatively new, instead of highlighting by decade as with citations, we list the top 50 downloaded conference proceedings papers.

Most of the papers are from the last 10 years ( $n = 41$ , with only three pre-2000). None of the top downloaded papers were papers selected by the JMI editorial committee. Eleven papers were common to the download and citation lists: papers 7, 9, 10, 30, 35, 39, and 41 corresponding to the 2010 to 2019 list; papers 29 and 38 from the 2000 to 2009 list; and papers 21 and 50 from 1998.

Surprisingly, the top downloaded paper ( $n = 4030$ ), by Wu et al., has only been cited 11 times.

### 3.3 Personal Favorites

Here, we list papers chosen by some members of the JMI Editorial Board, the person who chose it, and a brief explanation of why they did. The papers are listed in chronological order. The first two papers listed were also among the most cited papers.

**Table 1** The top 10 cited papers published in the SPIE Medical Imaging conference proceedings by decade.

Authors	Title	Year	Proceedings title	Volume	Number of citations
Years: 1972 to 1979					
Bunch et al. <sup>1</sup>	A free-response approach to the measurement and characterization of radiographic-observer performance	1977	Application of Optical Instrumentation in Medicine VI	127	199
Winkler <sup>2</sup>	Quality control in diagnostic radiology	1975	Application of Optical Instrumentation in Medicine IV	70	71
Frost et al. <sup>3</sup>	A digital video acquisition system for extraction of subvisual information in diagnostic medical imaging	1977	Application of Optical Instrumentation in Medicine VI	127	34
Yester and Barnes <sup>4</sup>	Geometrical limitations of computed tomography (CT) scanner resolution	1977	Application of Optical Instrumentation in Medicine VI	127	33
Jucius and Kambic <sup>5</sup>	Radiation dosimetry in computed tomography (CT)	1977	Application of Optical Instrumentation in Medicine VI	127	33
Wagner and Weaver <sup>6</sup>	An assortment of image quality indexes for radiographic film-screen combinations – can they be resolved?	1972	Application of Optical Instrumentation in Medicine I	35	26
Burgess et al. <sup>7</sup>	Detection of bars and discs in quantum noise	1979	Application of Optical Instrumentation in Medicine VII	173	20
Kinsey et al. <sup>8</sup>	Application of digital image change detection to diagnosis and follow-up of cancer involving the lungs	1975	Application of Optical Instrumentation in Medicine IV	70	16
Hanson <sup>9</sup>	Detectability in the presence of computed tomographic reconstruction noise	1977	Application of Optical Instrumentation in Medicine VI	127	15
Doi and Rossmann <sup>10</sup>	Evaluation of focal spot distribution by RMS value and its effect on blood vessel imaging in angiography	1974	Application of Optical Instrumentation in Medicine III	47	14
Years: 1980 to 1989					
Lewitt et al. <sup>11</sup>	Fourier method for correction of depth-dependent collimator blurring	1989	Medical Imaging III: Image Processing	Volume	Citing Works Count
Evans et al. <sup>12</sup>	Anatomical-functional correlative analysis of the human brain using three-dimensional imaging systems	1989	Medical Imaging III: Image Processing	1092	108

**Table 1** (Continued).

Authors	Title	Year	Proceedings title	Volume	Number of citations
LeFree et al. <sup>13</sup>	Digital radiographic assessment of coronary arterial geometric diameter and videodensitometric cross-sectional area	1986	Application of Optical Instrumentation in Medicine XIV and Picture Archiving and Communication Systems	1092	106
Pizer et al. <sup>14</sup>	Adaptive histogram equalization for automatic contrast enhancement of medical images	1986	Application of Optical Instrumentation in Medicine XIV and Picture Archiving and Communication Systems	626	60
Gamboa-Aldeco et al. <sup>15</sup>	Correlation of 3D surfaces from multiple modalities in medical imaging	1986	Application of Optical Instrumentation in Medicine XIV and Picture Archiving and Communication Systems	626	42
Hoffmann et al. <sup>16</sup>	Automated tracking of the vascular tree in DSA images using a double-square-box region-of-search algorithm	1986	Application of Optical Instrumentation in Medicine XIV and Picture Archiving and Communication Systems	626	41
Hanson <sup>17</sup>	Variations in task and the ideal observer	1983	Application of Optical Instrumentation in Medicine XI	626	40
Hohne et al. <sup>18</sup>	Display of multiple 3D-objects using the generalized voxel-model	1988	Medical Imaging II	419	39
Kuklinski et al. <sup>19</sup>	Application of fractal texture analysis to segmentation of dental radiographs	1989	Medical Imaging III: Image Processing	914	35
Loo et al. <sup>20</sup>	An empirical investigation of variability in contrast-detail diagram measurements	1983	Application of Optical Instrumentation in Medicine XI	1092	34
Years: 1990 to 1999					
Evans et al. <sup>21</sup>	Warping of a computerized 3-D atlas to match brain image volumes for quantitative neuroanatomical and functional analysis	1991	Medical Imaging V: Image Processing	1445	190
Udupa et al. <sup>22</sup>	3DVIEWNIX: an open, transportable, multidimensional, multimodality, multiparametric imaging software system	1994	Medical Imaging 1994: Image Capture, Formatting, and Display	2164	129
Abboud et al. <sup>23</sup>	Finite element modeling for ultrasonic transducers	1998	Medical Imaging 1998: Ultrasonic Transducer Engineering	3341	119
Lee et al. <sup>24</sup>	New digital detector for projection radiography	1995	Medical Imaging 1995: Physics of Medical Imaging	2432	115
McKeighen <sup>25</sup>	Design guidelines for medical ultrasonic arrays	1998	Medical Imaging 1998: Ultrasonic Transducer Engineering	3341	94

**Table 1** (Continued).

Authors	Title	Year	Proceedings title	Volume	Number of citations
Seibert et al. <sup>26</sup>	Flat-field correction technique for digital detectors	1998	Medical Imaging 1998: Physics of Medical Imaging	3336	92
Barrett et al. <sup>27</sup>	Stabilized estimates of Hotelling-observer detection performance in patient-structured noise	1998	Medical Imaging 1998: Image Perception	3340	78
Hasegawa et al. <sup>28</sup>	Description of a simultaneous emission-transmission CT system	1990	Medical Imaging IV: Image Formation	1231	74
Cotton and Claridge <sup>29</sup>	Developing a predictive model of human skin coloring	1996	Medical Imaging 1996: Physics of Medical Imaging	2708	71
Koch et al. <sup>30</sup>	X-ray camera for computed microtomography of biological samples with micrometer resolution using Lu <sub>3</sub> Al <sub>5</sub> O <sub>12</sub> and Y <sub>3</sub> Al <sub>5</sub> O <sub>12</sub> scintillators	1999	Medical Imaging 1999: Physics of Medical Imaging	3659	70
Chaussat et al. <sup>31</sup>	New CsIa-Si 17 x 17 X-ray flat panel detector provides superior detectivity and immediate direct digital output for general radiography systems	1998	Medical Imaging 1998: Physics of Medical Imaging	3336	70
Years: 2000 to 2009					
Mertelmeier et al. <sup>32</sup>	Optimizing filtered backprojection reconstruction for a breast tomosynthesis prototype device	2006	Medical Imaging 2006: Physics of Medical Imaging	6142	157
Gueld et al. <sup>33</sup>	Quality of DICOM header information for image categorization	2002	Medical Imaging 2002: PACS and Integrated Medical Information Systems: Design and Evaluation	4685	148
Lehmann et al. <sup>34</sup>	The IRMA code for unique classification of medical images	2003	Medical Imaging 2003: PACS and Integrated Medical Information Systems: Design and Evaluation	5033	144
Seifert et al. <sup>35</sup>	Hierarchical parsing and semantic navigation of full body CT data	2009	Medical Imaging 2009: Image Processing	7259	128
Clunie <sup>36</sup>	Lossless compression of grayscale medical images: effectiveness of traditional and state of the art approaches	2000	Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues	3980	111
Mizutani et al. <sup>37</sup>	Automated microaneurysm detection method based on double ring filter in retinal fundus images	2009	Medical Imaging 2009: Computer-Aided Diagnosis	7260	97

**Table 1 (Continued).**

Authors	Title	Year	Proceedings title	Volume	Number of citations
Michael Fitzpatrick <sup>38</sup>	Fiducial registration error and target registration error are uncorrelated	2009	Medical Imaging 2009: Visualization, Image-Guided Procedures, and Modeling	7261	95
Zou and Silver <sup>39</sup>	Analysis of fast kV-switching in dual energy CT using a pre-reconstruction decomposition technique	2008	Medical Imaging 2008: Physics of Medical Imaging	6913	89
Lankton et al. <sup>40</sup>	Hybrid geodesic region-based curve evolutions for image segmentation	2007	Medical Imaging 2007: Physics of Medical Imaging	6510	89
Bissonnette et al. <sup>41</sup>	Digital breast tomosynthesis using an amorphous selenium flat panel detector	2005	Medical Imaging 2005: Physics of Medical Imaging	5745	88
Years: 2010 to 2019					
Cruz-Roa et al. <sup>42</sup>	Automatic detection of invasive ductal carcinoma in whole slide images with convolutional neural networks	2014	Medical Imaging 2014: Digital Pathology	9041	261
Bar et al. <sup>43</sup>	Deep learning with non-medical training used for chest pathology identification	2015	Medical Imaging 2015: Computer-Aided Diagnosis	9414	187
Roth et al. <sup>44</sup>	Deep convolutional networks for pancreas segmentation in CT imaging	2015	Medical Imaging 2015: Image Processing	9413	109
Sun et al. <sup>45</sup>	Computer aided lung cancer diagnosis with deep learning algorithms	2016	Medical Imaging 2016: Computer-Aided Diagnosis	9785	108
Hwang et al. <sup>46</sup>	A novel approach for tuberculosis screening based on deep convolutional neural networks	2016	Medical Imaging 2016: Computer-Aided Diagnosis	9785	86
Liu et al. <sup>47</sup>	Prostate cancer diagnosis using deep learning with 3D multiparametric MRI	2017	Medical Imaging 2017: Computer-Aided Diagnosis	10134	72
Wang et al. <sup>48</sup>	Cascaded ensemble of convolutional neural networks and handcrafted features for mitosis detection	2014	Medical Imaging 2014: Digital Pathology	9041	71
Kappler et al. <sup>49</sup>	First results from a hybrid prototype CT scanner for exploring benefits of quantum-counting in clinical CT	2012	Medical Imaging 2012: Physics of Medical Imaging	8313	68
Kim et al. <sup>50</sup>	A deep semantic mobile application for thyroid cytopathology	2016	Medical Imaging 2016: PACS and Imaging Informatics: Next Generation and Innovations	9789	66
Anirudh et al. <sup>51</sup>	Lung nodule detection using 3D convolutional neural networks trained on weakly labeled data	2016	Medical Imaging 2016: Computer-Aided Diagnosis	9785	62

**Table 2** The top 50 downloads for papers published in the SPIE Medical Imaging conference proceedings.

	Authors	Title	Year	Volume	Number of downloads
1	Wu et al. <sup>52</sup>	Fully automated chest wall line segmentation in breast MRI using context information	2012	8315	4030
2	Fang et al. <sup>53</sup>	Unsupervised learning-based deformable registration of temporal chest radiographs to detect interval change	2020	11313	2528
3	Koenrades et al. <sup>54</sup>	Validation of an image registration and segmentation method to measure stent graft motion on ECG-gated CT using a physical dynamic stent graft model	2017	10134	2112
4	Wegmayr et al. <sup>55</sup>	Classification of brain MRI with big data and deep 3D convolutional neural networks	2018	10575	1878
5	Ayyagari et al. <sup>56</sup>	Image reconstruction using priors from deep learning	2018	10574	1858
6	Ruiter et al. <sup>57</sup>	USCT data challenge	2017	10139	1707
7	Bar et al. <sup>43</sup>	Deep learning with non-medical training used for chest pathology identification	2015	9414	1457
8	Mattes et al. <sup>58</sup>	Nonrigid multimodality image registration	2001	4322	1398
9	Cruz-Roa et al. <sup>42</sup>	Automatic detection of invasive ductal carcinoma in whole slide images with convolutional neural networks	2014	9041	1304
10	Sun et al. <sup>45</sup>	Computer aided lung cancer diagnosis with deep learning algorithms	2016	9785	1300
11	Alex et al. <sup>59</sup>	Generative adversarial networks for brain lesion detection	2017	10133	1290
12	Ramachandran S et al. <sup>60</sup>	Using YOLO based deep learning network for real time detection and localization of lung nodules from low dose CT scans	2018	10575	1183
13	Umehara et al. <sup>61</sup>	Super-resolution convolutional neural network for the improvement of the image quality of magnified images in chest radiographs	2017	10133	1174
14	Madani et al. <sup>62</sup>	Chest x-ray generation and data augmentation for cardiovascular abnormality classification	2018	10574	1142
15	Gjesteby et al. <sup>63</sup>	Deep learning methods to guide CT image reconstruction and reduce metal artifacts	2017	10132	1122
16	Jnawali et al. <sup>64</sup>	Deep 3D convolution neural network for CT brain hemorrhage classification	2018	10575	1096
17	Wei et al. <sup>65</sup>	Anomaly detection for medical images based on a one-class classification	2018	10575	1048
18	Eppenhof et al. <sup>66</sup>	Deformable image registration using convolutional neural networks	2018	10574	1005
19	Vassallo et al. <sup>67</sup>	Hologram stability evaluation for Microsoft HoloLens	2017	10136	1002
20	Dong et al. <sup>68</sup>	Sinogram interpolation for sparse-view micro-CT with deep learning neural network	2019	10948	983
21	Seibert et al. <sup>26</sup>	Flat-field correction technique for digital detectors	1998	3336	838

**Table 2 (Continued).**

	Authors	Title	Year	Volume	Number of downloads
22	Bowles et al. <sup>69</sup>	Modelling the progression of Alzheimer's disease in MRI using generative adversarial networks	2018	10574	815
23	Funke et al. <sup>70</sup>	Generative adversarial networks for specular highlight removal in endoscopic images	2018	10576	807
24	Duric et al. <sup>71</sup>	Breast imaging with the SoftVue imaging system: first results	2013	8675	786
25	Choi et al. <sup>72</sup>	Fast low-dose compressed-sensing (CS) image reconstruction in four-dimensional digital tomosynthesis using on-board imager (OBI)	2018	10573	782
26	Mescher and Lemmer <sup>73</sup>	Hybrid organic-inorganic perovskite detector designs based on multilayered device architectures: simulation and design	2019	10948	777
27	Jerman et al. <sup>74</sup>	Beyond Frangi: an improved multiscale vesselness filter	2015	9413	771
28	Lauritsch and Haerer <sup>75</sup>	Theoretical framework for filtered back projection in tomosynthesis	1998	3338	750
29	Mizutani et al. <sup>37</sup>	Automated microaneurysm detection method based on double ring filter in retinal fundus images	2009	7260	735
30	Roth et al. <sup>44</sup>	Deep convolutional networks for pancreas segmentation in CT imaging	2015	9413	735
31	de Vos et al. <sup>76</sup>	2D image classification for 3D anatomy localization: employing deep convolutional neural networks	2016	9784	727
32	Ionita et al. <sup>77</sup>	Challenges and limitations of patient-specific vascular phantom fabrication using 3D Polyjet printing	2014	9038	724
33	Clark et al. <sup>78</sup>	Multi-energy CT decomposition using convolutional neural networks	2018	10573	715
34	Peng et al. <sup>79</sup>	Design, optimization and testing of a multi-beam micro-CT scanner based on multi-beam field emission x-ray technology	2010	7622	712
35	Liu et al. <sup>47</sup>	Prostate cancer diagnosis using deep learning with 3D multiparametric MRI	2017	10134	702
36	Tsehay et al. <sup>80</sup>	Convolutional neural network based deep-learning architecture for prostate cancer detection on multiparametric magnetic resonance images	2017	10134	686
37	Graff <sup>81</sup>	A new, open-source, multi-modality digital breast phantom	2016	9783	684
38	Mertelmeier et al. <sup>32</sup>	Optimizing filtered backprojection reconstruction for a breast tomosynthesis prototype device	2006	6142	671
39	Hwang et al. <sup>46</sup>	A novel approach for tuberculosis screening based on deep convolutional neural networks	2016	9785	660
40	Hamidian et al. <sup>82</sup>	3D convolutional neural network for automatic detection of lung nodules in chest CT	2017	10134	636
41	Anirudh et al. <sup>51</sup>	Lung nodule detection using 3D convolutional neural networks trained on weakly labeled data	2016	9785	632
42	Moriya et al. <sup>83</sup>	Unsupervised segmentation of 3D medical images based on clustering and deep representation learning	2018	10578	623



**Table 2 (Continued).**

	Authors	Title	Year	Volume	Number of downloads
43	Almazroa et al. <sup>84</sup>	Retinal fundus images for glaucoma analysis: the RIGA dataset	2018	10579	620
44	Niemeijer et al. <sup>85</sup>	Comparative study of retinal vessel segmentation methods on a new publicly available database	2004	5370	618
45	Maier et al. <sup>86</sup>	Deep scatter estimation (DSE): feasibility of using a deep convolutional neural network for real-time x-ray scatter prediction in cone-beam CT	2018	10573	612
46	Zhang and Xing <sup>87</sup>	CT artifact reduction via U-net CNN	2018	10574	608
47	McKeighen <sup>25</sup>	Design guidelines for medical ultrasonic arrays	1998	3341	604
48	Pohle and Toennies <sup>88</sup>	Segmentation of medical images using adaptive region growing	2001	4322	592
49	Moore et al. <sup>89</sup>	OMERO and Bio-Formats 5: flexible access to large bioimaging datasets at scale	2015	9413	592
50	Gaonkar et al. <sup>90</sup>	Deep learning in the small sample size setting: cascaded feed forward neural networks for medical image segmentation	2016	9785	588

### 3.3.1 *An assortment of image quality indexes for radiographic film-screen combinations: can they be resolved?*

Wagner and Weaver<sup>6</sup>

Kyle Myers: Bob Wagner's 1972 paper on figures of merit launched his career and began that long trajectory of papers at SPIE Medical Imaging that pushed forward the development of figures of merit for the evaluation of medical imaging systems. Note that it was presented at the first Medical Imaging meeting.

Christoph Hoeschen: I also really liked that paper when coming across this nearly 30 years after it had been published, really explaining a lot to me. Currently, some approaches of vendors and regulators in Europe are looking again into potentially useful figures of merit in medical imaging especially in CT.

### 3.3.2 *Variations in task and the ideal observer*

Hanson<sup>17</sup>

Jeffrey Siewerdsen: Ken Hanson was one of the giant pioneers of modern image science (alongside Wagner, Myers, and Barrett and some others), and I always found Ken's formulation of "task" in a mathematical sense to be so enjoyable and profound. He was not alone, of course—joined by those other giants—but I always found his papers on "task" to focus on the task concept in ways that were beautifully explained both analytically and intuitively. I believe it made its way in to ICRU 54, and it was my original inspiration for "task-based optimization" for digital x-ray detectors etc. and of course, he was at least 25 years ahead of his time regarding "task-based" assessment of image quality, which is now ubiquitous in a more general sense.

### 3.3.3 *Principles governing the transfer of signal modulation and photon noise by amplifying and scattering mechanisms*

Dillon et al.<sup>91</sup>

Robert Nishikawa: This paper launched research into cascaded linear systems analysis. It was the beginning of intense investigation by several groups, including Rabbani, Van Metter and Shaw, Nishikawa and Yaffe, Cunningham, Siewerdsen, Maidment, Zhao, and others. From this research emerged the field of virtual clinical trials.

### **3.3.4** *Detection and discrimination of known signals in inhomogeneous, random backgrounds*

Barrett et al.<sup>92</sup>

Kyle Myers: Over the next years at SPIE Medical Imaging, starting in 1981, there were some back-and-forth papers by Harry Barrett (who was working on coded apertures for nuclear medicine applications) and Bob Wagner (who in 1981, published a paper that coded apertures could be inferior to an aperture with poor resolution), eventually leading them to co-write the paper from 1989 that tells a joint story. In a nutshell (last line of the abstract), “predictions of image quality based on stylized tasks with uniform background must be viewed with caution.” We can trace virtual clinical trials back to these early works.

### **3.3.5** *Clinical evaluation of PACS: modeling diagnostic value*

Kundel et al.<sup>93</sup>

Elizabeth A. Krupinski: I like this paper because it, very early on in PACS development, put the user center-stage and focused on the importance of the user, task, information flow and diagnostic value and outcomes. These principles remain critical today in any system evaluation, but are often not taken into account. This paper reminds us that the user/radiologist should drive technology adoption and implementation not just the availability of technology.

### **3.3.6** *Mammographic structure: data preparation and spatial statistics analysis*

Burgess<sup>94</sup>

Christoph Hoeschen: The paper of Art Burgess was actually presented in the first SPIE Medical Imaging conference I had the chance to attend. At that time, I was trying in my PhD thesis to determine the information content of structures in real patient images. The paper by Art Burgess showed how important approaches are to characterize content of the images. Since he is referring to the power spectrum of the images it is a little different approach than what I did but it showed the general importance very well. His paper was mentioned in various later contributions trying for example to build detection tasks and characterizing the background for this. Actually, in a current approach for a project funded by the European Commission (EC), where we try to determine objective image quality from patient images and relate this to subjective image quality measures, we use the power spectrum again. In addition, I think the paper is mathematically very clear and well written.

Robert Nishikawa: While not the first paper to study anatomical noise and human and model observers, it established the power law relationship of mammographic anatomical noise and its effect on lesion detectability. Burgess showed, what was at the time unintuitive, that anatomic noise was the dominant noise source for detecting masses, and that quantum noise was only important for the detection of microcalcifications. This research was the starting point for studies on the design of anatomical phantoms, detectability in two-dimensional (2D) versus three-dimensional (3D) imaging, improving task-based modeling and analyses, and model observer studies using more realistic backgrounds.

### **3.3.7** *Megalopinakophobia: its symptoms and cures*

Barrett et al.<sup>95</sup>

Mathew Kupinski: This paper is extremely useful as it describes a number of methods for dealing with large matrices and the computation of image quality for the Hotelling observer and other similar observer models. I also really enjoy the cheekiness of the paper as the title word

“megalopinakophobia” translates to “fear of large matrices.” This paper could easily have been a peer-reviewed publication but represents a great contribution to the SPIE literature.

### **3.3.8** *Content-based image retrieval in medical applications for picture archiving and communication systems*

Lehmann et al.<sup>96</sup>

### **3.3.9** *Extended query refinement for content-based access to large medical image databases.*

Lehmann et al.<sup>97</sup>

Thomas M. Deserno: Content-based image retrieval (CBIR) was introduced to medical applications in the early 2000s. Since then, CBIR has been applied in medical research and is now established in some commercial systems, too. Presented almost 20 years ago at Medical Imaging, these SPIE papers<sup>96,97</sup> were one of the first transferring CBIR into the medical domain, long before the follow-ups were published peer-reviewed in the *Methods of Information in Medicine* (2004)<sup>98</sup> and in the *Journal of Digital Imaging* (2008),<sup>99</sup> respectively. The latter received the *Journal of Digital Imaging* 2008 Best Paper Award, First Place (technical). This demonstrates that outstanding research is presented at SPIE Medical Imaging a couple of years before it becomes published in journals. This is the reason why I’m enjoying the meeting year by year, as so many new ideas are presented here first.

### **3.3.10** *Comparative study of retinal vessel segmentation methods on a new publicly available database*

Niemeijer et al.<sup>85</sup>

Ronald Summers: This paper is an early example of a publicly released dataset for algorithm performance comparisons. It has been cited 511 times according to Web of Knowledge [the most according to a search for “SPIE Medical Imaging” that found 28,828 results from the Conference Proceedings Citation Index—Science (CPCI-S)]. Publicly released datasets have had a major impact on the development of object recognition, segmentation, and computer-aided diagnosis across many areas of medical imaging. Challenges (competitions) using public datasets have inspired many trainees and early career investigators to specialize in medical image analysis.

### **3.3.11** *Reader error, object recognition, and visual search*

Kundel<sup>100</sup>

### **3.3.12** *How to minimize perceptual error and maximize expertise in medical imaging*

Kundel<sup>101</sup>

Claudia Mello-Thoms: The reason why I selected these papers is because reader error in medical imaging is still at the same rates that it was 40 years ago when Dr. Kundel started doing his research, despite the advances in technology. In these papers,<sup>100,101</sup> he created a taxonomy of error where he divided them in three categories, technological (which is not common), perceptual and cognitive. Perceptual errors are still responsible for about 60% of false negatives in medical imaging, whereas cognitive errors are responsible for about the remaining 40%. Despite the many interventions derived to improve the rates of perceptual errors, they all have failed, and we still do not understand what really causes these errors. We know that visual search plays a role in both perceptual and cognitive errors, but we don’t know how to improve visual search so as to reduce the 40 million errors per year that occur worldwide in medical imaging.

### 3.3.13 *Mitosis detection in breast cancer pathology images by combining handcrafted and convolutional neural network features*

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Anant Madabhushi: The paper set the stage for combining hand-crafted engineered feature approaches with deep learning for breast cancer digital pathology. While a number of papers have subsequently dealt with the topic of combining hand-crafted and deep learning based approaches for digital pathology and medical imaging applications, this was one of the early examples showing the possibility of this type of integration. This conference proceeding was ultimately published in JMI. At the time of writing the journal version of the paper was the second most highly cited paper in JMI (266), the conference paper has been cited over a 100 times already.

## 4 Concluding Remarks

As highlighted here, papers presented at the SPIE Medical Imaging conference have had a large and significant impact on the field of medical imaging. The meeting has grown over the last 50 years to become one of the most important meetings on the technical and practical aspects of medical imaging, for the latest concept and results are presented in SPIE Medical Imaging proceedings, long before they get published in the established journals in our field. In 2000, SPIE published the three-volume *Handbook of Medical Imaging*.<sup>103–105</sup> Many of the authors of this compendium were regular attendees of the SPIE Medical Imaging conference, and they provided a comprehensive overview of the many topics presented at the meeting.

## Disclosures

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