

Critical Comparison of Digital Pathology Systems

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Digital pathology is slowly gaining acceptance in both the clinical and research markets, and this is due in part to the wide spectrum of whole-slide scanning systems in the market today. However, whole slide scanning on its own is not sufficient. In order for digital pathology to be fully embraced by both clinical and research pathologists, image acquisition must be bundled with comprehensive image analysis applications and image management systems to provide a total digital pathology solution.

Whole-slide image acquisition is only partially useful on its own. Without reliable, stable, flexible, secured, and compliant image management of these whole-slide images, archiving and sharing becomes a serious problem. In addition, without being able to store metadata with the images and search for whole-slide images, pathologists can not fully benefit from them. Furthermore, image analysis on these whole-slide images can significantly reduce the time spent analyzing/screening these images and can also significantly improve patient care.¹ Therefore, a total digital pathology solution, incorporating image analysis and image management will drive the pathology industry digital.

In this paper, I critically evaluate 9 digital pathology systems and compare their image acquisition, image analysis, and image management capabilities against each other. In addition, I also provide a basic cost analysis. I evaluate the number of supported algorithms, progress with FDA clearance, supported image formats, ability to support remote viewing and sharing of images, and their supported magnifications of image acquisition, along with several other features. I also evaluate each solution in terms of its completeness as a digital pathology solution.

A complete digital pathology solution can significantly improve patient care and shorten research and development cycles. It can also simplify the sharing of data between collaborators and facilitate virtual second opinions. As a result, a total digital pathology solution can improve the current practice of pathology.

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	Biolmagene TissueMine	Biolmagene PATHIAM	Aperio Scanscope	Hamamtsu Nanozoomer	Zeiss Mirax
Total Digital Pathology Solution					
Image Analysis	Yes	Yes	Yes	No	Yes
Image Management	Yes	Yes	Yes	Yes	Yes
Image Processing	Yes	Yes	No	No	No
Image Acquisition	Yes	Yes	Yes	Yes	Yes
Integration Capabilities	Yes	Yes	No	No	No
Image Analysis					
Number of algorithms	33	27	5	0	1
Morphology based algorithms	Yes	Yes	No	No	No
Whole slide image analysis	Yes	Not Applicable	No	No	No
Whole Tissue Micro Array Analysis	Yes	Not Applicable	No	No	No
Workflow: Batch Image Analysis	Yes	Yes	No	No	No
Research: Manual Gridding of Tissue Micro Array (TMA)	Yes	Not Applicable	Yes	Yes	Yes
Research: Color Deconvolution	No	No	Yes	No	No
Research Rare event detection	Yes	Not Applicable	Yes	No	No
Research Microvessel density	Yes	Not Applicable	No	No	No
Research Automatic gridding of Tissue Micro Array (TMA)	Yes	Not Applicable	No	No	No
IT: Server Operating System	Windows, Linux, Solaris, Unix	Windows, Linux, Solaris, Unix	Windows	Windows	Windows
IT: Client Operating System	Windows	Windows	Windows	Windows	Windows
IHC: Research Nuclear	Yes	Not Applicable	Yes	Yes	No
IHC: Research Membrane	Yes	Not Applicable	Yes	Yes	No
IHC: Research Cytoplasm	Yes	Not Applicable	No	Yes	No
IHC: Prostate TFF	Yes	Yes	No	No	No
IHC: Prostate PAP	Yes	Yes	No	No	No
IHC: Prostate p27	Yes	Yes	No	No	No
IHC: Prostate p21	Yes	Yes	No	No	No
IHC: Prostate MIB-1	Yes	Yes	No	No	No
IHC: Prostate AR	Yes	Yes	No	No	No
IHC: Colon p53	Yes	Yes	No	No	No
IHC: Colon p27	Yes	Yes	No	No	No
IHC: Colon EGFR	Yes	Yes	No	No	No
IHC: Colon AE1/AE3	Yes	Yes	No	No	No
IHC: Breast PR	Yes	Yes	No	No	No
IHC: Breast p53	Yes	Yes	No	No	No
IHC: Breast Ki67	Yes	Yes	No	No	No
IHC: Breast HER2	Yes	Yes	No	No	No
IHC: Breast ER	Yes	Yes	No	No	No
IHC: Breast EGFR	Yes	Yes	No	No	No
IHC: Breast AE1/AE3	Yes	Yes	No	No	No
H&E: Tubule Identification	Yes	Yes	No	No	No
H&E: Nuclear Pleiomorphism	Yes	Yes	No	No	No
H&E: Mitosis	Yes	Yes	No	No	No
FISH Vysis	Yes	Yes	No	No	No
FISH Urovysion (2 and 4 probe)	Yes	Yes	No	No	No
FISH Pathvysion (2 probe)	Yes	Yes	No	No	No
FDA pending marker(s)	Not Applicable	5	0	0	0
FDA cleared marker(s)	Not Applicable	1	0	0	0
DNA Ploidy	Yes	Yes	No	No	No
Compatability: Other scanner vendors	Yes	Yes	No	No	No
Compatability: Digital Camera / Microscope systems	Yes	Yes	No	No	No
CISH	Yes	Yes	No	No	No

	Trestle	DMetrix	Ventana	Applied Imaging	DAKO
	DSM	DX40	VIAS	Ariol	ACIS III
Total Digital Pathology Solution					
Image Analysis	No	No	Yes	Yes	Yes
Image Management	Yes	Yes	No	No	No
Image Processing	No	No	No	No	No
Image Acquisition	Yes	Yes	Yes	Yes	Yes
Integration Capabilities	No	No	No	No	No
Image Analysis					
Number of algorithms	0	0	5	9	6
Morphology based algorithms	No	No	No	No	No
Whole slide image analysis	No	No	No	No	No
Whole Tissue Micro Array Analysis	No	No	No	No	No
Workflow: Batch Image Analysis	No	No	No	No	No
Research: Manual Gridding of Tissue Micro Array (TMA)	No	No	No	Yes	Yes
Research: Color Deconvolution	No	No	No	No	No
Research Rare event detection	No	No	No	Yes	Yes
Research Microvessel density	No	No	No	Yes	Yes
Research Automatic gridding of Tissue Micro Array (TMA)	No	No	No	No	No
IT: Server Operating System	Windows	Windows	Windows	Windows	Windows
IT: Client Operating System	Windows	Windows	Windows	Windows	Windows
IHC: Research Nuclear	No	No	No	No	No
IHC: Research Membrane	No	No	No	No	No
IHC: Research Cytoplasm	No	No	No	No	No
IHC: Prostate TFF	No	No	No	No	No
IHC: Prostate PAP	No	No	No	No	No
IHC: Prostate p27	No	No	No	No	No
IHC: Prostate p21	No	No	No	No	No
IHC: Prostate MIB-1	No	No	No	No	No
IHC: Prostate AR	No	No	No	No	No
IHC: Colon p53	No	No	No	No	No
IHC: Colon p27	No	No	No	No	No
IHC: Colon EGFR	No	No	No	No	No
IHC: Colon AE1/AE3	No	No	No	No	No
IHC: Breast PR	No	No	Yes	Yes	Yes
IHC: Breast p53	No	No	Yes	No	No
IHC: Breast Ki67	No	No	Yes	No	No
IHC: Breast HER2	No	No	Yes	Yes	Yes
IHC: Breast ER	No	No	Yes	Yes	Yes
IHC: Breast EGFR	No	No	No	No	No
IHC: Breast AE1/AE3	No	No	No	No	No
H&E: Tubule Identification	No	No	No	No	No
H&E: Nuclear Pleiomorphism	No	No	No	No	No
H&E: Mitosis	No	No	No	No	No
FISH Vysis	No	No	No	Yes	No
FISH Urovisyon (2 and 4 probe)	No	No	No	Yes	No
FISH Pathvisyon (2 probe)	No	No	No	Yes	No
FDA pending marker(s)	0	0	0	0	0
FDA cleared marker(s)	0	0	5	3	3
DNA Ploidy	No	No	No	Yes	Yes
Compatability: Other scanner vendors	No	No	No	No	No
Compatability: Digital Camera / Microscope systems	No	No	No	No	No
CISH	No	No	No	No	No

	Biolmagene TissueMine	Biolmagene PATHIAM	Aperio Scanscope	Hamamtsu Nanozoomer	Zeiss Mirax
Image Management					
Number of Supported Image Formats	81	81	7	7	7
IT: Web Based	Yes	Yes	Yes	Yes	Yes
IT: Supports LIMS/LIS integration	Yes	Yes	Yes	No	Yew
IT: Supports workflow integration	Yes	Yes	Yes	Yes	Yes
IT: Supports remote viewing	Yes	Yes	Yes	Yes	Yes
Conferencing	Yes	Yes	Yes	Yes	Yes
Supports metadata	Yes (unlimited)	Yes (unlimited)	Yes (limited)	Yes (limited)	Yes (limited)
Batch loading of metadata	Yes	Yes	No	No	No
Annotation	Yes	Yes	Yes	Yes	Yes
Reporting	Yes	Yes	Yes	Yes	Yes
Customized Reporting	Yes	Yes	No	No	No
Supports realtime gross images	Yes	Yes	Yes	Yes	Yes
21 CFR part 11 Compliant	Yes	Yes	No	No	No
GLP Compliant	Yes	Yes	No	No	No
HIPAA Compliant	Yes	Yes	Yes	No	No
IT: Server Operating System	Windows, Linux, Solaris, Unix, Apple	Windows, Linux, Solaris, Unix, Apple	Windows	Windows, Apple	Windows
IT: Client Operating System	Windows, Linux, Solaris, Unix, Apple	Windows, Linux, Solaris, Unix, Apple	Windows, Apple	Windows, Apple	Windows
IT: Browser compatibility	IE, Mozilla, Safari, Netscape, Opera	IE, Mozilla, Safari, Netscape, Opera	IE, Mozilla, Safari, Netscape, Opera	IE, Netscape, Mozilla, Opera, Safari	IE, Netscape, Mozilla, Opera
Search: Simple	Yes	Yes	Yes	Yes	Yes
Search: Boolean	Yes	Yes	Yes	No	No
Image Processing					
Supports Single Processor	Yes	Yes	Yes	Yes	Yes
Server side processing	Yes	Yes	No	No	No
Client side processing	Yes	Yes	No	No	No
Distributed Image Processing (clustering)	Yes	Yes	No	No	No
3D	No	No	Yes	Yes	Yes
Image Acquisition					
Slide input	1x3; 2x3	1x3; 2x3	1x3, 2x3	1x3	1x3
Brightfield	Yes	Yes	Yes	Yes	Yes
Fluorescence	No	No	No	Yes	Yes
Barcode	1D, 2D	1D, 2D	1D, 2D	1D, 2D	1D, 2D
Flatpanel LCD Monitor	Yes	Yes	Yes	Yes	Yes
File output	JPEG, JPEG2000, TIFF	JPEG, JPEG2000, TIFF	JPEG, JPEG2000, TIFF	JPEG, TIFF	JPEG, TIFF
Slide capacity	160	160	1, 5, 120	210	50, 300
Speed 15x15mm @20x (min)	5	5	3	5	10
Installations	1	1	200	10	5
Pixel Resolution	0.46/0.23	0.46/0.23	0.50/0.25	0.46/0.23	0.23*
100 Oil	No	No	Yes	No	No
True 40X scan	Yes	Yes	Yes	Yes	Yes
Platform	Scanner	Scanner	Scanner	Scanner	Scanner
Integration Capabilities					
D3 Methodology	Yes	Yes	No	No	No
Methodology Success	Yes	Yes	No	No	No
Integration LIMS	Yes	Yes	No	No	No
Integration LIS	Yes	Yes	No	No	No
Workflow Customization	Yes	Yes	No	No	No
Cost Structure					
Initial Investment	49K - 99K	5K	49K - 149K	180K	49K - 149K
Recurring Investment (monthly)	0	2K	0	0	0
Recurring Support (annual)	9K - 18K	0	9K - 24K	30K	9K - 24K
Per-use Fee (slide creation)	0	\$0.99	0	0	0
Per-use Fee (test)	0	\$9.99	0	0	0

	Trestle	DMetrix	Ventana	Applied Imaging	DAKO
	DSM	DX40	VIAS	Ariol	ACIS III
Image Management					
Number of Supported Image Formats	7	7	Does Not Support	Does Not Support	Does Not Support
IT: Web Based	Yes	Yes	Does Not Support	Does Not Support	Does Not Support
IT: Supports LIMS/LIS integration	No	Yes	Does Not Support	Does Not Support	Does Not Support
IT: Supports workflow integration	Yes	Yes	Does Not Support	Does Not Support	Does Not Support
IT: Supports remote viewing	Yes	Yes	Does Not Support	Does Not Support	Does Not Support
Conferencing	Yes	No	Does Not Support	Does Not Support	Does Not Support
Supports metadata	Yes (limited)	Yes (limited)	Does Not Support	Does Not Support	Does Not Support
Batch loading of metadata	No	Does Not Support	Does Not Support	Does Not Support	Does Not Support
Annotation	Yes	Yes	Does Not Support	Does Not Support	Does Not Support
Reporting	Yes	Yes	Does Not Support	Does Not Support	Does Not Support
Customized Reporting	No	Does Not Support	Does Not Support	Does Not Support	Does Not Support
Supports realtime gross images	Yes	Does Not Support	Does Not Support	Does Not Support	Does Not Support
21 CFR part 11 Compliant	No	Does Not Support	Does Not Support	Does Not Support	Does Not Support
GLP Compliant	No	Does Not Support	Does Not Support	Does Not Support	Does Not Support
HIPAA Compliant	No	Does Not Support	Does Not Support	Does Not Support	Does Not Support
IT: Server Operating System	Windows	Windows	Does Not Support	Does Not Support	Does Not Support
IT: Client Operating System	Windows, Apple	Windows, Apple	Does Not Support	Does Not Support	Does Not Support
IT: Browser compatibility	IE, Netscape, Mozilla, Opera, Safari	IE, Netscape, Mozilla, Opera, Safari	Does Not Support	Does Not Support	Does Not Support
Search: Simple	Yes	Yes	Does Not Support	Does Not Support	Does Not Support
Search: Boolean	No	No	Does Not Support	Does Not Support	Does Not Support
Image Processing					
Supports Single Processor	Yes	No	Yes	Yes	Yes
Server side processing	No	No	No	No	No
Client side processing	No	No	No	No	No
Distributed Image Processing (clustering)	No	No	No	No	No
3D	No	No	No	No	No
Image Acquisition					
Slide input	1x3, 2x3	1x3	1x3	1x3	1x3
Brightfield	Yes	Yes	Yes	Yes	Yes
Fluorescence	No	No	No	Yes	No
Barcode	None	1D, 2D	1D	1D	1D
Flatpanel LCD Monitor	Yes	Yes	Yes	Yes	Yes
File output	JPEG, TIFF	JPEG	JPEG	JPEG, TIFF	JPEG, TIF
Slide capacity	1, 4, 8, 50	40	1	50	100
Speed 15x15mm @20x (min)	10	1	Does Not Support	16	36
Installations	100	5	100	150	150
Pixel Resolution	0.46	0.46			
100 Oil	No	No			
True 40X scan	No	No	Does Not Support	Yes	Yes
Platform	Microscope	Scanner	Microscope	Microscope	Scanner
Integration Capabilities					
D3 Methodology	No	No	No	No	No
Methodology Success	No	No	No	No	No
Integration LIMS	No	No	No	No	No
Integration LIS	No	No	No	No	No
Workflow Customization	No	No	No	No	No
Cost Structure					
Initial Investment	49K - 149K	200K	0	225K	180K
Recurring Investment (monthly)	0	0	3.3K	0	0
Recurring Support (annual)	9K - 24K	40K	0	50K	30K
Per-use Fee (slide creation)	0	0	Does Not Support	0	0
Per-use Fee (test)	0	0	\$50	0	0

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Refereed and Non-Refereed Journals:

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18. Zhao, Y, Yagi, Y., et al: A Study of Wireless IP for Telemedicine. The Fourth International Symposium on Wireless Personal Multimedia Communications-Conference Proceeding, Vol.3 of 3, Pages 1597-1600, 2001
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ABSTRACTS / INVITED LECTURES

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22. Yagi, Y.: The Development of Multipurpose Virtual Telepathology :Advancing Pathology Informatics, Imaging, and the Internet 99, USA, 1999
23. Yagi, Y.: The Development of Multipurpose Virtual Telepathology :Advancing Pathology Informatics, Imaging, and the Internet 99, USA, 1999
24. Yagi, Y, Gilbertson, J.: Initial Experiences with a Mobile Computer System for Anatomic Pathology: Advancing Pathology Informatics, Imaging, and the Internet 2000, USA, 2000
25. Yagi, Y, Gilbertson, J.: Mobile Devices for Anatomic Pathology: United States and Canadian Academy of Pathology, USA, 2001
26. Yagi, Y, Special Invited Lecture: Faculty of Engineering Tokyo Institute of Technology, Japan, 2001
27. Yagi, Y, Special Invited Lecture: TAO, Ministry of Telecommunication and Post office, Japan, 2001
28. Yagi, Y, Special Invited Lecture: University of Kyushu Medical School, Japan, 2001

29. Yagi, Y., Minervini, M., et al: Telepathology for Organ Transplantation; American Telemedicine Association, USA, 2001
30. Yagi, Y., Gilbertson, J: Portable Telepathology: Mobile Devices for Anatomic Pathology, Banff Allograft Conference, Canada, 2001
31. Yagi, Y., Gilbertson, J: Can Multi-spectral high resolution cameras change pathology? Banff Allograft Conference, Canada, 2001
32. Yagi, Y: Mobile Telepathology over Wireless Network, YRP 2001, Denmark, 2001
33. Nakajima, I, Yagi, Y. et al: High Elliptical Orbiter for Motion Picture Transmission from Ambulance, YRP 2001, Denmark
34. Nakajima, I, Yagi, Y. et al: A Comparison of the Cost Analysis Models between the 3rd Generation Mobile communications and High Elliptical Orbit Satellites < Aiming at the Nation Wide Pre-hospital Care on Ambulance > YRP 2001, Denmark, 2001
35. Yagi, Y: Digital Stain: APIII 2001.
36. Yagi, Y. Implementation of Telepathology in Clinical Practices, Telemedicine Workshop of WHO/UN/ITU, Egypt, 2001.
37. Yagi, Y., Special Invited Lecture: TAO, Ministry of Telecommunication and Post office, Japan, 2002
38. Yagi, Y., Special Invited Lecture: Tokai University Medical School, Japan, 2002
39. Yagi, Y., Nakajima, I et al: Development of UDP-IP Based VSAT system for ETS-VIII, American Institute of Aeronautics and Astronautics, 20th International Communications Satellite Systems, Canada, 2002
40. Huzoji, H., Yagi, Y., et al: Design and Prototype of Satellite Track with Quadrant Detector for Ambulances, American Institute of Aeronautics and Astronautics, 20th International Communications Satellite Systems, Canada, 2002
41. Session Chair for Cooperative and National Research Program 2, American Institute of Aeronautics and Astronautics, 20th International Communications Satellite Systems, Canada, 2002
42. Invited lectures at Mediterranean Summer School Telemedicine, by Association Italian Telemedicine and Medical Informatics, Palermo, Italy, 2002
43. Yagi, Y., Weinstein, R: Telepathology Tutorial, American Telemedicine Association, USA, 2002
44. Yagi, Y: Special Invited Lecture at The Medical Information System Development Center, Japan, 2002
45. Yagi, Y: Special Invited Lecture at Japan Telepathology Association, Japan 2002
46. Yagi, Y: Invited Lecture Telepathology-Virtual Slide; Virtual Slide Symposium, SC, USA, 2002
47. Yagi, Y., Special Invited Lecture: TAO, Ministry of Telecommunication and Post office, Japan, 2003
48. Yagi, Y., Special Invited Lecture: Technological Innovation in Hospital: from stethoscope to telemedicine, Italian Embassy, Egypt, 2003
49. Yagi, Y: Invited lecture: Telepathology; 1st Pan Arab Congress & Fair of I.T in Medicine, Egypt, 2003
50. Yagi, Y: Special Invited Lecture: Telepathology & Pathology Imaging, ; University of Milan, Italy, 2003
51. Yagi, Y: Development of a real-time, intraoperative teleneuropathology system, the UPMC Health System experience. APIII 2003
52. Yagi, Y: Multi-Spectral Imaging Application in Pathology. APIII 2003
53. Yagi, Y: Linear transformation of spectral transmittance in application to digital staining of unstained tissue sample image. APIII 2003
54. Yagi, Y: Standardization of stain condition. APIII 2003

55. Yagi, Y: Spectral transmittance measurement method using consumer based digital camera. APIII 2003
56. Yagi, Y: Comparison of stain quantification for histological specimens using spectrometer and multi-band image data. APIII 2003
57. Yagi, Y: Telepathology Special Interest Group Forum. Annual Conference of American Telemedicine Association, 2003
58. Yagi, Y: Implementing Telepathology in a Complex Distributed Medical Center. Annual Conference of American Telemedicine Association, 2003
59. Yagi, Y: Special Lecture. Current Status of Telepathology and Pathology Imaging. National Vision Research Center, Japan, 2004.
60. Patel A. Gupta R, Yagi Y, Gilbertson J. Large scale implementation of whole slide imaging in a tissue bank. MedInfo 2004
61. Inaugural Caribbean Telemedicine Symposium and Exhibition, Kingston, Jamaica, July 2004 (National Commission on Science and Technology and The Embassy of the United States in Jamaica) Invited Lecture: Telepathology
62. Regional Seminar on "The role of Information & Communication technology in protecting Man and Environment: How to limit the impact of its use", Cairo, Egypt, Oct, 2004 (UN, ITU, LAS, UNEP, WHO) *Keynote Speech *Session Chair for the ICT Equipment Industry:Health and Environmental Impacts and its safe Management *Invited lecture: Next Generation IC Card System *Invited lecture:Establishment of E-Health Network for Disaster and Healthcare Improvement: Integrated Medical Information Technology System
63. Yagi, Y: Whole Slide Imaging Applications in Telepathology, 3rd Asia Pacific Telecommunity Telmedicine Workshop, Kuala Lumpur, Malaysia, Jan 2005
64. Yagi, Y: Large Scale Implementation of Whole Slide Imaging in a Tissue Bank, SPIE Medical Imaging, San Diego, Feb 2005
65. Yagi, Y: Special Lecture. Current Status of Telepathology and Pathology Imaging. National Vision Research Center, Japan, May 2005
66. Yagi Y: Special Lecture. Integrated Medical Information Technologies Project, Okinawa, Japan. May 2005
67. Yagi Y: World Wide Telepathology Network using MedMicroscopy and System Development, Japan Telepathology Association Conference, Japan, August 2005 (Japanese)
68. Yagi Y: The Combination of Telepathology and Virtual Slide as an Application in Digital Pathology, Japan Telepathology Association Conference, Japan, August 2005 (Japanese)
69. Yagi Y: System Development & Applications of Micro Array Ultra Rapid Virtual Slide Scanning System, Japan Telepathology Association Conference, Japan, August 2005 (Japanese)
70. Yagi Y, Jukic D, et al: The Integration of Whole Slide Imaging in the Clinical Anatomic Pathology – Limitations of Laboratory Information Systems, Image Capture Systems and Archives, DICOM 2005 International Conference & Seminar, Hungary, Sept 2005
71. Yagi, Y: Automated Whole Slide Imaging in Quality Assurance, 4th Asia Pacific Telecommunity Telmedicine Workshop, Rawalpindi, Pakistan, Jan 2006
72. Yagi, Y: Automated IT Requirements for High Volume Slide Digitization , 8th European Congress on Telepathology and 2nd International Congress on Virtual Microscopy, Budapest, Hungary, July 2006