

Evaluation of Free Non-Diagnostic DICOM Software Tools

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ABSTRACT

A variety of software exists to interpret files or directories compliant to the Digital Imaging and Communications in Medicine (DICOM) standard and display them as individual images or volume rendered objects. Some of them offer further processing and analysis features. The surveys that have been published so far are partly not up-to-date anymore, and neither a detailed description of the software functions nor a comprehensive comparison is given. This paper aims at evaluation and comparison of freely available, non-diagnostic DICOM software with respect to the following aspects: (i) data import; (ii) data export; (iii) header viewing; (iv) 2D image viewing; (v) 3D volume viewing; (vi) support; (vii) portability; (viii) workability; and (ix) usability. In total, 21 tools were included: 3D Slicer, AMIDE, BioImage Suite, DicomWorks, EViewBox, ezDICOM, FPIImage, ImageJ, JiveX, Julius, MedImaView, MedINRIA, MicroView, MIPAV, MRICron, Osiris, PMSDView, Syngo FastView, TomoVision, UniViewer, and XMedCon. Our results in table form can ease the selection of appropriate DICOM software tools. In particular, we discuss use cases for the inexperienced user, data conversion, and volume rendering, and suggest Syngo FastView or PMSDView, DicomWorks or XMedCon, and ImageJ or UniViewer, respectively.

Keywords: PACS, DICOM, Software, Comparison, Evaluation

1. INTRODUCTION

After acquiring 2D and 3D medical datasets in the Digital Imaging and Communications in Medicine (DICOM) format using computed radiology (CR), magnet resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET) or other modalities, one often wants to view the data before starting to process them. To do so, DICOM software tools are needed which should meet certain requirements. While there are many commercial products on the market such as Materialize™, DICOMatic™ etc, a variety of freely available DICOM software tools also exist, which turn out to be good alternatives of their commercial counterparts.

In 2003, Horii [1] described some free non-diagnostic DICOM software tools, but on the one hand, some of them are no longer available and some features may have been altered, and on the other hand, in the mean time there are many new software tools. He also mentioned the trial version of some commercial products which can only be used for a short term such as 20 months. Furthermore, Horii makes no comparisons but explicitly states that he was not aiming at providing a comprehensive comparison of the software tools [1].

There are also some websites [2,3,4] which provide up-to-date listings of existing free non-diagnostic DICOM software tools. However, the descriptions for these software tools are rather brief, if any. Furthermore, there is neither an evaluation nor a comparison of them. Therefore, selecting an appropriate tool for a certain requirement is a challenging problem in both research and application.

This paper presents a systematic evaluation and comparison of prominent but freely available DICOM software tools, which are not designed for the diagnostic purposes. We also consider some free, functionally restricted versions of commercial products or trial versions. As a result from the exhaustive comparison, we provide the users help when choosing appropriate software tools to satisfy their needs.

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2. CATALOG OF CRITERIA

In this survey, the terms *image*, *series* and *dataset* are used in the following way: a dataset consists of one or more series; a series is the result of a single scanning process and can contain several images.

For entries contained as tags in the DICOM header, we differentiate between two types. Both of the two types have a unique tuple of numbers as identification, such as (0008, 0060). The first type of tags is common DICOM information. Such tags have additional mnemonic names. For example, (0008, 0060) means “modality”. The correspondences between identification and meanings are recorded in “dictionaries” for the software tools. We will refer to them as *common tags*. The other type of tags is often specific to the scanner vendors and there are no common mnemonic names for them. We will refer to them as *specific tags*.

In order to refer to the criteria in the result section easily, the criteria are enumerated with a capital letter such as A, B, etc. All criteria have more than one sub-criterion, which are indicated with an additional number such as A1, A2, etc. For the sake of objectivity, most criteria were designed such that they can be evaluated simply as “yes” or “no”. However, for some aspects a more detailed evaluation is needed. Here, we use “+”, “0” or “-” to indicate whether the software tool is *good*, *neutral*, or *bad*.

2.1. Data Import

DICOM data must be loaded before being viewed. All the software tools we evaluated can import DICOM data directly or easily convert DICOM into their specific format, but their import mechanisms have quite different qualities. Obviously, it is desirable to load images together which belong to the same series. The essential information which describes how the individual DICOM files compose series is not the file name, but rather the tags contained the DICOM header. It is usual that more than one series reside in the same directory and the file names can not tell the difference among them but are simply consecutively numbered. In this case, if a software tool tries to load DICOM images merely according to the file names of the images, the result could be quite messy. It is ideal that the software tool scans the entire directory recursively and analyzes the structure of the dataset using headers of the individual DICOM images, and then provides an overview of all series in the directory and its sub-directories (Figure 1).

A1 – Image: The software tool can load one single DICOM images.

A2 – Set: The user selects a set of DICOM images or a directory and the software automatically loads all selected images or all images in the selected directory, regardless whether these images belong to the same series or not, i.e. the images are loaded without respecting the DICOM header information.

A3 – Series: The user specifies one DICOM image and – based on their header information – the software tool searches further DICOM images within the same directory which belongs to the same series as the user-specified image, the other series are ignored and no overview is made.

A4 – Directory: The software tool scans the directory, but not its sub-directories, and provides an overview of all datasets and their series within the scanned directory.

A5 – Tree: The software tool scans the entire directory recursively and provides an overview of all datasets and their series within the current directory and all its sub-directories so that the user can easily select the desired series.

2.2. Data Export

It is often desired to convert DICOM images to other formats for other purposes. It turns out that the DICOM software tools have quite different abilities to perform this operation.

B1 – Image: The most basic export functionality is to save a single image in other formats. Most of the DICOM software tools are able to do this to a certain degree, i.e. some of them can export images into a variety of formats, while the others can only export one or two formats.

B2 – Series: If the user would like to export all images in a series, it is cumbersome to do it for each individual image. It would be practical if they can be exported once and named automatically and systematically.

B3 – Dataset: If all images in an entire dataset are needed, it is far more convenient to export them once than doing it for each individual images or series.

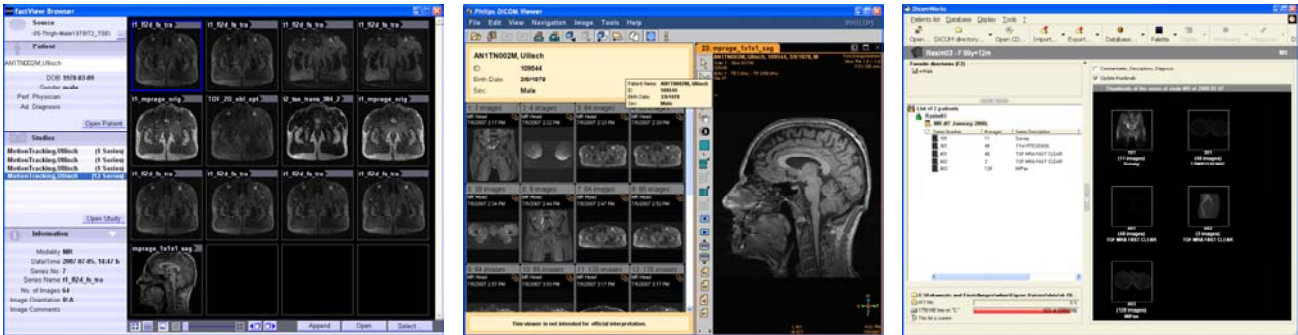


Figure 1: Data Import with Syngo FastView (*left*), PMSDView (*middle*), and DicomWorks (*right*)

B4 –Sequence: Instead of exporting the images in a series into static images, it is also possible to export them as frames in order to build a sequence to be shown by media players.

B5 – Gallery: Some software tools provide the nice utensil to make an HTML gallery for all images in the same series. The thumbnails of exported images are shown in the HTML site, hyperlinked with the full-size exported image.

2.3. Header Viewing

Beside images, viewing related tags such as the image resolution is important. DICOM header tags also provide valuable information about the studies, e.g. imaging modality, scanner type, and parameters for the study. While not directly related to viewing data, these tags are still an integral part of DICOM and can be useful for the user. Since the number of DICOM header tags may vary strongly among individual datasets, it is difficult to give a quantitative evaluation. However, there are some software tools which only display one or two common tags such as acquisition location. In this case, we do not consider them as having the header display ability.

C1 – Image: The software tool can display common image-related tags, e.g. dimensions of images, etc.

C2 – Study: The software tool can display common study-related tags like scanner type, acquisition parameters, etc.

C3 – Vendor: The software tool can display specific tags which depend on vendor.

2.4. 2D Image Viewing

All DICOM software tools must at least be able to show the 2D DICOM images. The following functionalities make this task more efficient and convenient.

D1 –Windowing: The windowing function controls the brightness and contrast of the images. Not always are the default windowing function settings optimal and the user should have the possibility to adjust them manually.

D2 – Pseudo-Color: Most DICOM images are gray scale and there is only contrast between different gray levels. By using pre-defined pseudo-color look up tables (LUT), gray levels can be mapped onto pseudo-colors to enhance the visual effect of the images.

D3 – Histogram: Histogram is an important description of gray scale images. Since most DICOM images are gray scale, it should be possible to display their histograms.

D4 – Information Overlay: When viewing an image, it is helpful to have an overview of some basic information about it, such as the image dimensions, acquisition parameters, current position in the series, etc. Instead of looking up these issues in the DICOM header for each image, it is convenient that such information is overlaid to the current image in the display window and updated automatically when scrolling through the images of a series.

D5 – Measurement: Since DICOM header contains information about the real distance between two pixels, e.g. in cm, it is possible to compute distances between landmarks in the image. Angles can also be measured easily since they do not depend on scaling. By intuitively drawing lines, the user should be able to measure lengths and angles in the image.

D6 – Annotation: For some issues, it is required to annotate images and save these annotation in the image bitmap.

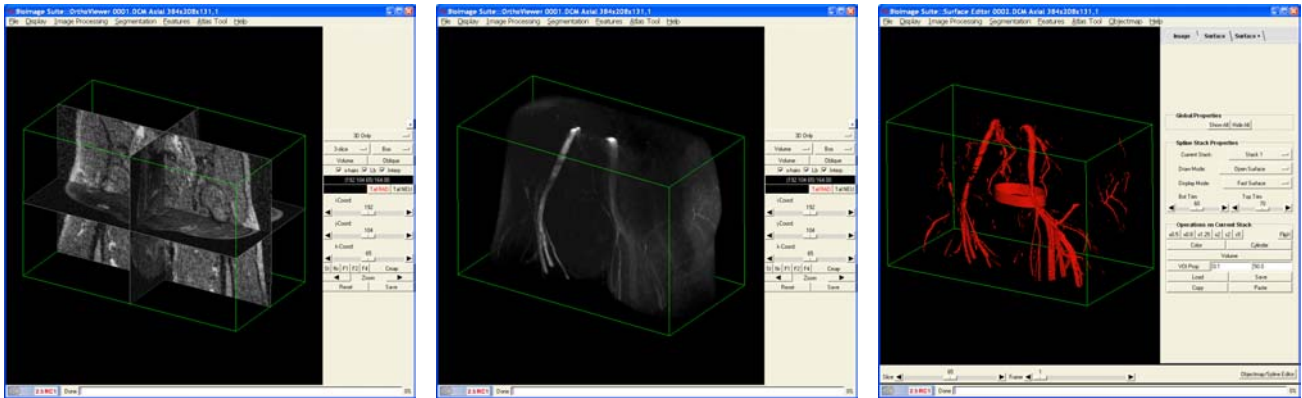


Figure 2: 3D Volume Visualization: Slice cube (*left*), volume rendering (*middle*), iso-surface (*right*)

2.5. 3D Volume Viewing

A lot of medical imaging modalities produce 3D data, i.e. all images in a series form a volume. Beyond 2D viewing, the data can also be visualized directly in 3D, which gives a much deeper spatial illusion (Figure 2).

E1 – Slice Scrolling: If all images of a series, which represents a volume, are loaded and one of them is displayed, it is convenient to view the previous and next images simply by scrolling using either the mouse wheel or the up and down keys on the keyboard.

E2 – Secondary Reconstruction: Medical volume data is acquired in one direction, e.g. the transversal direction. If the images can be viewed in other directions, e.g. in sagittal and coronal directions, then the user can gain improved impression of the structures which can be best viewed in a particular direction. To do so, the software tool must be able to reconstruct the secondary views out of the primary one.

E3 – Slice Cube: Although the volumetric presentation is illustrative, viewing the slices, either alone in 3D or overlaid to the volume, can better visualize the details at a particular 3D position. The user should be able to adjust the positions of transversal, sagittal and coronal slices while the slices themselves are shown in 3D and in a separate display as well (Figure 2, left).

E4 – Volume Rendering: Direct volume rendering provides the ability to visualize the 3D images directly as volumes so that the user can view them interactively by rotating, translating and scaling them (Figure 2, middle). Maximum intensity projection and texture mapping are the most frequent implemented algorithms for direct volume rendering.

E5 – Transfer Function: The opacities of voxels are controlled by the transfer function which maps the gray level of the voxel onto opacity value. By correctly adjusting the transfer function, tissues with particular gray levels can be viewed more clearly, while tissues with other gray levels are transparent.

E6 – Surface Generation: Voxels with the same gray level build up iso-surfaces, and algorithms such as marching cubes can be applied to find such surfaces. Surface representations of 3D objects allow for fast interactive 3D rendering (Figure 2, right).

2.6. Support

When encountering problems or difficulties, supporting information is crucial. This includes the static support like documentation, interactive support like e-mail, forum and wiki, as well as source code of the software tool.

F1 – Documentation: A written documentation accompanying the software tool, which is always a valuable resource of support.

F2 – E-Mail: A mailing list exists to support the user.

F3 – Forum: A Web-based forum is provided for the software tool.

F4 – Wiki: The user can get further support from a wiki site of the software tool.

F5 – Source: The source code is available, which helps not only developers but also users to gain insight into the software and certain implementation of the algorithms. This is the greatest advantage of open source software in contrast to commercial products.

2.7. Portability

Obviously, a variety of operating systems are used by the user community. Portable software tools allow the users to work with his familiar GUI on different platforms and thus enhance the flexibility.

G1 – Windows: The software tool runs on MS Windows.

G2 – Linux: The software tool runs on Linux.

G3 – Mac: The software tool runs on Mac OS.

2.8. Workability

Storage space requirements and loading times majorly determine the workability of software, in particular, on less performing lap tops, notebooks and other portable computing devices.

H1 – Package Size: The package size determines the size of the downloaded software.

H2 – Installation Size: The installation size denotes the storage requirements after complete installation and decompression of all required files.

H3 – Initialization Time: The initialization time denotes the required time if the software tool has not yet been loaded into the computer's memory.

H4 – Reload Time: This measurement indicates how much time is needed to reload/restart the software tool.

2.9. Usability

In this criterion, the usability is evaluated. The evaluation is unavoidably subjective as it results from the authors' own experience.

I1 – Intuitiveness: The GUI of some software tool is so self-explanatory that it can be used in a very straightforward manner and the user does not need to read the manual at all, while other software tools cannot be used so intuitively and manual is urgently needed.

I2 – Response Speed: Some software tools react faster on user interaction than the others. The overall response speed of the GUIs are reviewed here.

I3 – Presentation Quality: In above criteria, we evaluate whether the software tools have some particular functionalities or not, but do not mention how well or ergonomically these functionalities are presented. This issue is captured here.

3. MATERIALS

3.1. Software Selection

Referring to the resources [2,3,4], almost 100 different tools can be found. We selected all DICOM software tools that were mentioned at least on two of the three listings, which are

1. free availability, i.e. the software tools are freely downloadable;
2. stand-alone, i.e. the software is not simply a plug-in for general purpose image viewer; and
3. graphical user interface (GUI)-based, i.e. the software tool is not driven by command line.

Since these criteria include MicroView as a vendor-provided tool (General Electric Healthcare), we additionally included Syngo FastView (Siemens AG) and PMSDView (Philips Medical Systems Nederland B.V.), which are more common on the European markets. This results in 21 tools (Table 1).

Table 1: DICOM Software tools evaluated in this survey.

1. EViewBox has no information about the version number;
2. FPIImage has a trial period of 30 days. After that, the product must be registered and purchased;
3. JiveX is a commercial product. We evaluate its free personal edition with limited functionalities. The current version of this personal edition will expire on 01. Jan. 2009.

Name	Version	URL
3D Slicer	2.7-opt	http://www.na-mic.org/Slicer/Download/Release
AMIDE	0.9.0	http://amide.sourceforge.net
BioImage Suite	2.5 Beta	http://bioimagesuite.org
DicomWorks	1.3.5	http://dicom.online.fr
EViewBox	-- ¹	http://eviewbox.sourceforge.net
ezDICOM	1.0	http://www.sph.sc.edu/comd/rorden/ezdicom.html
FPIImage ²	0.20	http://www.fpimage.com
ImageJ	1.38x	http://rsb.info.nih.gov/ij
JiveX ³	4.2.2	http://www.jpacs.com/DICOM_Viewer.59+M58a563e9a40.0.html
Julius	1.1	http://www.julius.caesar.de/index.php/Julius_MV1
MedImaView	0.9.2.0	http://www.dicom-solutions.com/medimaview.shtm
MedINRIA	1.6	http://www-sop.inria.fr/asclepios/software/MedINRIA/index.php
MicroView	2.1.2	http://microview.sourceforge.net
MIPAV	3.1.6	http://mipav.cit.nih.gov/clickwrap.php
MRIcon	Beta 7	http://www.sph.sc.edu/comd/rorden/mricron
Osiris	4.19	http://www.sim.hcuge.ch/osiris/01_Osiris_Presentation_EN.htm
PMSDView	R2.4L1-SP1	http://www.medical.philips.com/main/company/connectivity/
Syngo FastView	VX57F24	http://www.medical.siemens.com/
TomoVision	1.8 Rev-5c	http://www.tomovision.com
UniViewer	Mar 6 2007 10101	http://www.unipacs.com/en/uniView.html
XMedCon	0.10.2	http://xmedcon.sourceforge.net/

Some of them such as 3D Slicer, BioImage Suite or MIPAV are not restricted to simply viewing DICOM data but provide powerful algorithms for 3D image processing, registration and segmentation. However, those features were not in the scope of this review. Also it should be mentioned that MRIcon cannot load DICOM directly, but reads another popular format, i.e. the Neuroimaging Informatics Technology Initiative (NIfTI). While the extension of DICOM files is “.dcm” or “.ima”, NIfTI files have the extension “.nii” and “.nii.gz” for uncompressed and compressed versions, respectively. A DICOM to NIfTI conversion tool comes with the MRIcon package.

Due to its plug-in mechanism, ImageJ is very flexible and nearly arbitrarily extendable. Some of the plug-ins, e.g. the one for DICOM import, are now integrated as standard part of ImageJ, and a plenty of further ones can be found at the ImageJ Web site. For simplicity, we use ImageJ (and its standard plug-ins) with only one additional plug-in called Volume Viewer (FHTW University of Applied Science, Berlin, Germany) for volume rendering.

3.2. Testing Data

We used an arbitrary compilation of different DICOM data (Table 2). Datasets 1-22 are acquired ourselves, dataset 23 comes with 3D Slicer and datasets 24-28, whose DICOM header does not contain any information about equipment, come with Julius.

Table 2: Datasets used for evaluation

Dataset	Scanner	Series	Images	Size
1	Philips Gyroscan NT Intera	15	515	211
2	Philips Gyroscan NT Intera	14	475	206
3	Philips Gyroscan NT Intera	4	184	69
4	Philips Achieva	8	316	132
5	Philips Achieva	12	748	367
6	Philips Achieva	29	1993	846
7	Philips Achieva	14	579	526
8	Philips Achieva	5	238	220
9	Philips Intera	16	638	206
10	Philips Intera	10	667	387
11	Philips Intera	10	687	389
12	Philips Intera	10	665	387
13	Philips Intera	10	671	387
14	Philips Intera	10	676	396
15	Philips Intera	11	752	413
16	Philips Intera	7	281	111
17	Siemens TrioTim	7	204	294
18	Siemens TrioTim	1	39	22
19	Siemens TrioTim	31	945	254
20	Siemens TrioTim	13	1220	980
21	Siemens Avanto	7	281	205
22	Siemens Symphony	4	184	123
23	GE Genesis Signa	1	124	17
24	--	1	113	15
25	--	1	128	17
26	--	1	109	14
27	--	1	109	14
28	--	1	127	16

Table 3: Hardware of the machines used for evaluation

No	CPU	Graphics Card	Memory	Hard Disk	Graphics Memory
1	Intel® Core™ DUO CPU E4500, 2.2 GHz	GeForce 7300SE	4 GB	120 GB	512 MB
2	Intel® Pentium® 4 CPU 2.80 GHz	GeForce 5600XT	1 GB	80 GB	128 MB
3	Intel® Core™ 2 CPU T7200, 2.00 GHz	Intel® GMA 950	2 GB	20 GB	224 MB

3.3. Testing Environment

The tests are carried out on three different machines (Table 3). The desktop PC 1 runs MS Windows and Linux and is used for functionality tests and time measurements. Desktop 2 and Laptop 3 both are operated with MS Windows and are used for functionality tests. Since all measurements on Linux turned out to be quite similar to those obtained with MS Windows, we only present the latter.

4. RESULTS

The results of evaluation and comparison are shown in Tables 4 and 5. As can be seen, most viewers have the basic abilities to load a set of images, export single images, show the image related header tags, allow to adjust the windowing function and to navigate in the dataset by scrolling, and many of them come with documentation or further support. They all run on MS Windows, and some of them run additionally on Linux or MacOS. Regarding the workability, large differences exist. For instance, the installation size (criterion H2) varies from less than 1 MB to nearly 300 MB for EviewBox and BioImage Suite, respectively.

Regarding the export abilities, general purpose formats, especially jpg, are more widely supported than the medical imaging formats. There are some formats that are used exclusively in one software tool or locally e.g. at the institution where the tool is developed. Such formats are not listed in the table. In particular (i) INW(RUG): XMedCon format. It is only used at the Ghent University where XMedCon is developed; (ii) Papyrus: an image file format based on ACR-NEMA version 2.0. It is developed and used by the University Hospital of Geneva for their hospital-wide PACS; and (iii) INR: INRIA-Format. This is a format developed and used at the French National Institute for Research in Computer Science and Control (INRIA).

5. DISCUSSION

Obviously, there is no all-round best software tool which outperforms all the others. For example, 3D Slicer provides convenient ways to view 2D and 3D data and many algorithms for image processing, but it is rather slow and cannot always load the DICOM data conveniently, as indicated in the comparison table, nor is its usage intuitive due to its complicated menu structure. Syngo FastView can analyze the DICOM directories recursively and is very user-friendly, but it cannot perform volume rendering and is restricted on MS Windows.

Generally, performing volume rendering requires much more computing power than viewing images in 2D, which also must be considered at the software selection.

It must be clarified that the selection of appropriate software tools does not mean simply to choose the ones with the most dots in our tables but it always depends on need in concrete situations. Some issues such as pseudo-color are less important than other criteria such as reconstruction of sagittal and coronal views. Therefore, we particularly discuss three common use cases:

1. **Inexperienced User:** Directory overview is a very important functionality, especially for users with little DICOM experience since the DICOM directories are often not clearly structured, i.e. not always is each series in its own directory. The structure could sometimes be even very complicated, e.g. the images of the same series could be distributed in different directories, while images from different series share the same directory. When using some software tools which can scan the directory tree recursively, all the user needs to do is to specify a directory and let the software tool to load it. Then the user can see clearly how many series there are and how many images are in each individual series. Previews are also provided for each series. With other software tools which can only load one single image, even the total number of series in the dataset could be difficult to determine.

For a user who is new to DICOM and its software tools and wants to view the DICOM datasets easily as images (i.e. not as 3D volume rendered objects) on MS Windows without further image processing or exporting, then Syngo FastView is a very good choice, even on PC with moderate hardware, because of its intuitive usage, low system demands, and the possibility to show all existing tags in the DICOM header. All the user has to do to load the data is just to specify a directory and let Syngo FastView automatically analyze the structure of the directory, find out how many DICOM series reside in the directory, generate an overview of all these series, and make a preview and a simple description for each individual series. After that, the user can select the desired series according to the preview or description, easily adapt the windowing function, and scroll over all the images of the series. If needed, information from the DICOM header concerning size of the images, study date, etc. can be overlaid and updated while scrolling. It is also possible to view the series as images in sagittal and coronal directions. The PMSDView is also a good choice with nearly the same functionalities. A crucial difference is the lack of reconstruction of the sagittal and coronal views. While MIPAV can also do the job, it is in this case due to its high system demand and unintuitive usage not the first choice.

Software	Data Import					Data Export					Header View.			2D Image Viewing						3D Volume Viewing						Support				
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	D1	D2	D3	D4	D5	D6	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5
3D Slicer					• ¹	•					•			•	•	•				•	•	•	•	•		•	•			•
AMIDE	•			•		•	•							•	•	•				•	•		•	•		•	•			•
BiImage Suite	•		•			•	•				•			•	•	•				•	•	•	•	•	•	•		•		
DicomWorks	•				•	•	•	•	•	•	•	•	•	•			•	•	•	•								•		
EviewBox	•	•				•	•			•	•			•						•	•						•			•
EzDICOM	•	•				•					•	•	• ²	•			•			•						•				•
FPIImage	•	•				•					•	•		•		•	•	•	•	•						•				
ImageJ	•	•				•	•			•	•	•	•	•	•	•		•	•	•	•		•	•		•		•		•
JiveX ³	•				•									•			•	•	•	•						•				
Julius			•								•	•		•	•	•				•	•	•	•	•	•	•				
MedImaView	•					•								•	•															
MedINRIA					•	•					•			•	•		•			•	•		•	•		•	•	•		
MicroView	•	•				•					•			•	•	•				•	•	•	•	•	•					•
MIPAV	•	•			•	•	•			•	•	•	•	•	•	•	• ⁴		•	•	•	•	•	•	•	•	•			
MRICron ⁵						•								•	•	•			•	•	•		•	•		•				•
Osiris	•				•	•	•			•	•	•		•		•	•	•	•	•						•				•
PMSDView	•	•		•		•				•	•	•	•	•			•	•		•										
Syngo FastView	•				•	•				•	•	•	•	•			•	•		•	•					•				
TomoVision	• ⁶										• ⁷	•		•			•			•						•				
UniViewer	•	•			•	•	•	•	•		•	•	•	•			•	•		•			•	•						
XMedCon	• ⁸					•					•	•		•	•					•						•				•

Table 4: Evaluation results (Part 1)

- 3D Slicer can only scan the directory tree recursively if all images of a series are in the same directory and there are no other images in the same directory.
- Although ezDICOM can show the complete header list, we have observed that whenever the tag (0029, 1020) is encountered, none of the tags afterwards can be shown correctly.
- The export and header viewing functionalities are disabled in the free personal edition of JiveX.
- MIPAV allows the user to specify which DICOM header tags should be overlaid.
- MRICron cannot load DICOM images directly but it supplies a utensil program DCM2NII to easily convert DICOM into the NIfTI format which is the primary format of MRICron.
- TomoVision is limited to load only 5 DICOM images once.
- TomoVision itself can show the common tags in the header as image overlay but specific tags cannot be shown. In addition, TomoVision comes with a small utensil program called DICOMCompare which can show detailed header information of two DICOM images for comparison. However, DICOMCompare can only show the numeric names of the tags instead of the mnemonic names. For example, it just shows “(0018, 0025)” instead of the better readable name “Angio Flag”.
- XMedCon can read single DICOM images. To read more than one images or entire directories, the user has to either specify the header offset length and dimensions of the images manually, or convert all images first into a single NIfTI file which is readable for XMedCon.

Software	bmp	dcm	fits	gif	gipl	hdr	i33	ima	img	img.hdr	jpg	mha	mnc	nii	nrrd	pax	pbm	pcx	pgm	pict	png	ppm	psd	raw	tga	tiff	tla	txt	v	vff	vtk	wmf		
3D Slicer	.																					.			.									
AMIDE											
Biolmage Suite																										
DicomWorks	
EviewBox				.																														
EzDICOM	.										.																							
FPImage								
ImageJ	
JiveX																																		
Julius																																		
MedImaView	.										.																							
MedINRIA					
MicroView
MIPAV	
MRlcron	.												.																					
Osiris									
PMSDView	.										.																							
Syngo FastView	.										.																							
TomoVision																																		
UniViewer												
XMedCon	

Table 5: The export formats of software tools.

bmp:	bitmap;	pbm:	Portable Bitmap;
dcm:	DICOM 3.0;	pcx:	image format of ZSoft Corporation;
fits:	Flexible Image Transport System;	pgm:	Portable Graymap;
gif:	Graphics Interchange Format;	pict:	Mac Standard Metafile Format;
gipl:	Guys Image Processing Lab Format;	png:	Portable Network Graphics;
hdr:	Analyze Format;	ppm:	Portable Pixmap;
i33:	InterFile Format;	psd:	Adobe Photoshop Format;
ima:	ACR-NEMA 2.0;	raw:	image data in uncompressed format, without header;
img:	Ecat6;	tga:	Targa File Format;
img.hdr:	format for Concorde company's MicroPET Scanner;	tiff:	Tagged Image File Format;
jpg:	Joint Photographic Experts Group;	tla:	a password-protected format with lossless compression;
mha:	MetaImage Toolkit Format;	txt:	gray scales saved as matrix in a text file;
mnc:	MINC;	v:	Ecat7;
nii:	NIFTI;	vff:	Visualization File Format;
nrrd:	Nearly Raw Raster Data format;	vtk:	Visualization Toolkit Format;
pax:	a password-protected format with lossless compression;	wmf:	Windows Metafile Format.

Software	Portability			Workability				Usability		
	G1	G2	G3	H1	H2	H3	H4	I1	I2	I3
3D Slicer	•	•		36	131	26	13	-	-	+
AMIDE	•	•	•	12	47	2	0	+	+	+
BioImage Suite	•	•	•	82	298	6	1	-	-	+
DicomWorks	•			6	14	2	1	+	+	+
EviewBox	•	•	•	0	0	1	1	+	+	+
EzDICOM	•			2	3	1	1	+	+	-
FPIImage	•			4	7	2	1	+	+	0
ImageJ	•	•	•	21	93	2	1	+	+	+
JiveX	•			44	132	11	7	+	+	+
Julius	•	•		26	66	8	1	+	0	0
MedImaView	•			1	1	1	1	+	+	+
MedINRIA	•	•	•	9	25	5	4	+	0	+
MicroView	•	•	•	16	48	8	3	0	+	+
MIPAV	•	•	•	126	237	8	5	-	-	+
MRlcron ²	•	•	•	14	15	2	1	+	+	0
Osiris	•		•	4	9	1	1	0	+	+
PMSDView	•			28	28	8	7	+	+	+
Syngo FastView	•			53	67	1	1	+	+	+
TomoVision	•			1	2	1	1	+	+	+
UniViewer	•			1	3	1	1	0	+	+
XMedCon	•	•	•	4	10	1	1	+	+	+

Table 4: Evaluation results (Part 2).

2. **Data Conversion:** If the user also needs to convert or export DICOM data into other, mostly general purpose formats on MS Windows, then DicomWorks would be an effective tool. While Syngo FastView and PMSDView are only able to convert single DICOM images into a very limited number of formats, DicomWorks can convert single images, all images in a series or even in an entire dataset into many formats. When exporting many images in one run, it is possible to specify the names of the exported images in a manner similar to regular expression. It can even build an HTML gallery for the exported images. DicomWorks is also very powerful for viewing images but although supposed to be multilingual, the error messages are often displayed in French. For conversion between medical image formats, XMedCon is also a good choice. This finding corresponds to the ranking in [4].
3. **Volume Rendering:** If the user just wants to gain a first 3D illusion of a series but is not interested in more exhaustive algorithms for further processing like segmentation or registration, then it could be more appropriate to use smaller software tools such as ImageJ and Julius on both MS Windows and Linux, or UniViewer on MS Windows. They can be used easily and directly start the program, as it is, for instance, not the case with 3D Slicer. Furthermore, ImageJ is thanks to its plug-in mechanism strongly extendable. Indeed, there are already a plenty of ImageJ plug-ins for data loading, 2D and 3D rendering, image analysis algorithms, etc. The user can also write own plug-ins and let ImageJ integrate them automatically. Currently, ImageJ is the most popular software tool for viewing DICOM data for Windows, Linux and MacOS according to a ranking by [4]. Basing on Java, ImageJ is independent of operating systems, but the Java nature could also result in a slower execution time.

6. CONCLUSION

DICOM software tools have been developed rapidly in the recent years. Some of the tools mentioned in the survey [1] in 2003 are no longer available, and at the same time many new tools have been released. Even during the last few months between the submission of the abstract and full version of this paper, Syngo FastView and PMSDView have

improved their functionalities in new releases: Syngo FastView has now the ability to show the complete DICOM header, and PMSDView has become independent of an additional file “DICOMDIR” for localization of the datasets, which was mandatory for earlier versions. 3D Slicer is advancing on a daily basis, BioImage Suite has a new release, and MIPAV is extended with the volume rendering functionality. It is essential to have an overview about these software tools to work efficiently and effectively with DICOM datasets. Using our comparison tables, even a user without prior DICOM experience can select software tools which meet his need well and avoid being confused by the large number of them or looking for functionalities which do not exist.

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