MANIPULATION OF DICOM FORMAT IMAGES : Search of a visualization and manipulation environment for the generation of hybrid images

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ABSTRACT

This document is a work of revision with the objective of determining the optimal election of a viewer and modifier of images in DICOM format. This viewer should have a series of specific characteristics that allow the user to incorporate, in a simple and trustworthy way, tools of simulation and insertion of structures (injuries, backgrounds, etc.) on the image. The project is based upon the necessity of having databases of simulated images with structures, injuries or anatomical backgrounds that allow to make studies of perception and optimization of techniques and components. These databases are of prime interest in the Medical Image field, in teaching programs and, specially, in the quality programs of the Digital Image.

MATERIAL AND METHOD

The number of programs that manipulate or visualize medical images is of the order of 250, without counting on the proprietary programs associated to the medical image systems (x-ray, CT, MR, etc.) This amount of viewers has made it necessary to establish criteria of selection, based on the future use that is desired to give the chosen program. 24 criteria of sieve have been defined and have been scored like "essential" or "desirable", ordered in the following categories: capacity of manipulation, type of code, platform, DICOM characteristics, characteristics defined by IHE (Integrated the Healthcare Enterprise) and general characteristics. The application of these criteria has taken us to fix a set of requirements, justified in the present paper, that has been used as filter element on the total number of programs previously indicated. Basically these requirements are:

a) Ability to work with DICOM images.
b) Developed in Java.
c) Free license.
d) Open Source Software (OSS).

	Selection criteria	Des.	Ess.
A.	**Manipulation**		
1	Viewer with capacity of integration with other applications (user-exits, plugins, etc.)		X
2	Insertion of functions developed by other researchers (plugins, called to API, etc.)		X
3	Boolean and arithmetical functions that allow the merge of images.		X
4	Full functionality of standard image processing: adjustment of contrast, brightness, histograms, equalization, determination of ROI, etc.		X
B.	**Type of code**		
1	Developed as open software (OSS).		X
C	**Platform**		
1	Multiplatform		X
2	Compatibility with Windows O.S. of 32 bits		X
3	Java		X
D	**DICOM features**		
1	Reading of different varieties of DICOM format		X
2	Multi-image reading		X
3	Capacity of preserving anonymity		X
4	Reading of DICOM header		X
5	Maintaining the DICOM format after the manipulations.		X
E	**IHE standard**		
1	Support for storage and presentation of CAD data	X	
2	Specific graphics for mammograms	X	
F	**Features**		
1	Date of the latest version and number of versions released.		X
2	Community participant in its development.		X
3	Program documentation	X	
4	Presence of the program within the medical research community	X	
5	Availability of GUI (Graphical User Interface)		X
6	Connection with complex DICOM systems: databases, transmission TCP/IP, PACS, etc.	X	
7	Typical functionality of medical image processing.	X	
8	Specific medical filters (mammary radiography, chest radiography, etc.)	X	
9	Good performance in image processing.	X	

Des: Desirable **Ess:** Essential

Name	Author	Rev	Rev date
Blox	Patrick Barta	0.12b	11/26/00
BrainImageJava	SPNL	n.a.	n.a.
Dcm4che	Gunter Zellinger	1.4.8	02/19/07
DICOM Anonymizer	NeoLogica	1.1.5	10/01/05
DICOM Dumper	NeoLogica	1.1	n.a.
DICOM Java ImageIO SPI	S Shah	1.0	03/25/04
DICOM Plugins for ImageJ	Thomas Hacklaender	1.0.0	08/22/02
DICOM Viewer	Takahiro Katoji	1.0.0	02/21/05
DicomRouter	Thomas Hacklaender	4.1.0	11/17/06
DICOMscope	OFFIS Consortium	3.5.1	07/01/01
Eviewbox	Serge Derhy		11/18/01
ImageJ	Wayne Rasband	1.37	11/10/06
Imagemagick	ImageMagick Studio LLC	6.3.2	12/01/06
imRead	U. Colorado HSC Neuroradiology section	2.2	02/09/00
JDCM	JDCM	1.6	09/12/05
JDicom	Tiani	1.7.35	n.a.
JDICOMviewer	Serge Derhy	n.a.	n.a.
LONI Debabeler	LONI: UCLA Laboratory of Neuro Imaging	2.6	11/13/06
NeatMEd	Dublin City University	n.a.	n.a.
NeatVision	Dublin City University	2.1	10/15/03
PixelMed Java DICOM Toolkit	David A. Clunie	n.a.	05/08/04
SimpeDICOM	UPMC Univ. Pittsburgh	4.0	11/23/05
TOPPCAT	Daniel Barboriak	n.a.	04/15/04

Computer programmes able to manipulate images in DICOM format, developed in JAVA and under OSS license. 22 programs found.

RESULTS

On a first analysis, a subgroup of 22 programs seems to fulfil these requirements. Nevertheless, the characteristics of these applications have been analyzed in detail and have been found several disqualification criteria:

1. Some of the mentioned programs, although being able to handle DICOM images and modifying them, they lack the capacity to visualize them.
2. The licenses are not completely open (OSS). Some programs publish the source code, but they are not free. Others, on the other hand, are free, but their code is closed.
3. Not all of them are able to work with most DICOM formats. In fact, some of them are restricted to specific DICOM formats or restricted areas of the Medical Image (MR, CT, etc.)
4. Certain programs have a command console to execute the different actions, or they are simply formed by a library of functions. Nevertheless, neither of these types of programs have a Graphical User Interface (GUI)..
5. Some of the programs are excellent viewers, with magnificent functions of enhancement and outpost visualization but, analyzed in detail, they lack the minimum capacity to modify images or to insert functions that allow this modification.
6. Finally, some of these programs have very little use within the scientific community, compared with others of similar characteristics that have been much more tested, and with a high number of developments.

Name	Autor	Rev Date	Reason for refusal
DICOM Anonymizer	NeoLogica	10/01/05	Only eliminates the DICOM header information.
DICOM Dumper	NeoLogica	n.a.	It manages only the DICOM header.
imRead	U. Colorado HSC Neuroradiology section	02/09/00	It is free, but the source code is not available.
JDCM	JDCM	09/12/05	Only the evaluation version is free.
JDicom	Tiani	n.a.	Server toolset which does not have any viewer.
JDICOMviewer	Serge Derhy	n.a.	Only referenced in other webs. The original website does not exist.
LONI Debabeler	LONI: UCLA Laboratory of Neuro Imaging	11/13/06	It is an image converter.
NeatMEd	Dublin City University	n.a.	Server toolset, without any viewer.
SimpeDICOM	UPMC Univ. Pittsburgh	11/23/05	It is free, but the source code is not available yet.

FIRST FILTERING: They are not viewers or are not real OSS.

Name	Autor	Rev Date	Reason for refusal
Blox	Patrick Barta. Kennedy Krieger Institute, Johns Hopkins University,	11/26/00	The purpose of this project was to develop a tool for the quantitative analysis and display of images for use in brain MR and Molecular Imaging. The latest version is too old, 11/26/2000.
BrainImageJava	SPNL	n.d.	It is a multiplatform application, very oriented to process and display images. Specifically developed for brain image visualization.
DICOM Plugins for ImageJ	Thomas Hacklaender	08/22/02	It is an extension of ImageJ, so both must be evaluated together.
DICOMscope	OFFIS Consortium	07/01/01	It is a viewer of all modalities of DICOM image. It supports calibration of monitor. It was developed in 1999 and its latest version is from January 2001, too old.
Eviewbox	Serge Derhy	11/18/01	It is an OSS project to display different types of images, including the DICOM format. Only can display images and the latest version was launched in January 2001.
NeatVision	Dublin City University	10/15/03	It is a specialized software in analysis and presentation of multiformat images. It uses a large number of algorithms that, specifically, may be reused. The latest version was launched in 2002.
TOPPCAT	Daniel Barboriak	04/15/04	Only for MR studies

SECOND FILTERING: They are not focused to manage the different types of DICOM formats or are specialized in fields that are not of interest in our study or the latest version was launched before 2004.

Name	Description	Author	Rev	Rev Date	Reason for refusal (if applicable)
Dcm4che	DICOM Server and a toolset written in JAVA.	Gunter Zellinger	1.4.8	02/19/07	It is a powerful library of applications in Java to file, recovery and create workflows of medical documentation. It conforms to the standard DICOM and IHE, but is not a viewer, only an object manager. Its use can be very interesting as a library for systems integration. It is being used in integration projects as the one led by the Open Three Consortium.
DICOM Java ImageIO SPI	DICOM images display written in JAVA.	S Shah	n.d.	03/25/04	It is only a viewer without capacity to process or modify images. No use within the scientific community. Only one revision has been made since its launch in September 2003.
DICOM Viewer	Applet developed in Java to display images across the WWW, using an Internet browser.	Takahiro Katoji	1.0.0	02/21/05	It is an excellent applet to display DICOM images, but does not allow the image processing. All the algorithms for image processing should be developed. It has little use within the scientific community.
DicomRouter	Router DICOM developed in JAVA.	Thomas Hacklaender	4/1/0	11/17/06	It is not a viewer itself, but a library for linking different applications working in DICOM format. It use may be interesting as a supplement.
ImageJ	Processing and image analysis written in open code in Java.	**Wayne Rasband**	**1.37**	**11/10/06**	We think it is the right decision because is a good viewer and, overall, is an outstanding framework for the development of image processing functions. It is analyzed in the conclusions.
Imagemagick	Program library to convert, edit and compose images in different formats.	ImageMagick Studio LLC	6.3.2	12/01/06	Program library very comprehensive and very widespread use, especially in the field of comprehensive image processing, but it does not have a GUI. It would be an interesting second option and cannot be ruled out the idea of using functions of this library through its interface for Java, JMagick.
PixelMed Java DICOM Toolkit	DICOM library and tools.	David A. Clunie	n.d.	05/08/04	It has no GUI and the date of the latest version is prior to 2005. It has a little use within the scientific community.

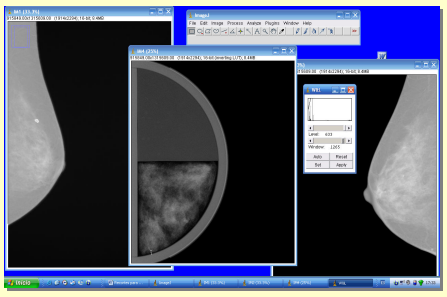
THIRD FILTERING: Not available GUI, are not image processors or have a little use within the scientific community.

CONCLUSIONS

After this analysis, the program that better fits with the specified criteria is **ImageJ, of Wayne Rasband**. The degree of fulfilment of ImageJ of the mentioned 24 criteria of selection has been analyzed in detail. We should emphasize that ImageJ does not fulfil them in their totality, not even some of the criteria defined as essential. Nevertheless, certain developments made by the scientific community around this program complement it until getting to fulfil the mentioned criteria. In fact, the high number of investigation teams that work using this program and share their results and developments with the rest of the scientific community, is one of the strongest characteristic of this application. Finally, the easiness of insertion of new developments within the structure of this program, the extensive library of functions developed by third parties, the relative easiness of programming in the Java environment and the portability of the developments, makes of this program a good choice for the objectives marked in the present study.

	Fulfilment of the criteria for ImageJ	Des.	Ess.
A.	**Manipulation**		
1	Viewer with capacity of integration with other applications (user-exits, plugins, etc.)		✔
2	Insertion of functions developed by other researchers (plugins, called to API, etc.)		✔
3	Boolean and arithmetical functions that allow the merge of images.		✔
4	Full functionality of standard image processing: adjustment of contrast, brightness, histograms, equalization, determination of ROI, etc.		✔
B.	**Type of code**		
1	Developed as open software (OSS).		✔
C	**Platform**		
1	Multiplatform		✔
2	Compatibility with Windows O.S. of 32 bits		✔
3	Java		✔
D	**DICOM features**		
1	Reading of different varieties of DICOM format		✔
2	Multi-image reading		✔
3	Capacity of preserving anonymity		✔
4	Reading of DICOM header		✔
5	Maintaining the DICOM format after the manipulations.		✔
E	**IHE standard**		
1	Support for storage and presentation of CAD data	■	
2	Specific graphics for mammograms	■	
F	**Features**		
1	Date of the latest version and number of versions released.		✔
2	Community participant in its development.		✔
3	Program documentation	✔	
4	Presence of the program within the medical research community	✔	
5	Availability of GUI (Graphical User Interface)		✔
6	Connection with complex DICOM systems: databases, transmission TCP/IP, PACS, etc.	✔	
7	Typical functionality of medical image processing.	■	
8	Specific medical filters (mammary radiography, chest radiography, etc.)	■	
9	Good performance in image processing.	✔	

Des: Desirable **Ess:** Essential ✔ : yes ✖ : no



Screen capture of ImageJ displaying two mammograms and one phantom

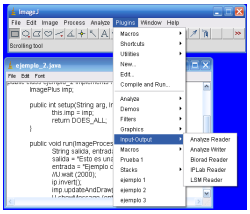
Filters

Real Convolver
FFT
LoG Filtering
Background Subtraction and Normalization
Contrast Enhancer
Background Correction
Byte Swapper
Discrete Cosine Transform (DCT)
FFT Filter
FFTJ and DeconvolutionJ
Unpack 12-bit Images
De-interlace
2D Gaussian Filter
Kalman Filter
Dual-Energy Algorithm
Anisotropic Diffusion
Mixture Modeling Thresholding
Otsu Thresholding
Watershed Segmentation
Grayscale Morphology
Maximum Entropy Thresholding
2D Hybrid Median Filter
3D Hybrid Median Filter
Spectral Unmixing
Haar Wavelet Filter and Adaptive Median Filter
'A trous' Wavelet Filter
MultiThresholder (Isodata, Entropy, Otsu…)
Kuwahara Filter
Granulometric Filtering
Windowed-Sinc Filter (low pass time series)
Anisotropic Diffusion 2D
Auto Gamma (gamma correction)
Linearize Gel Data
Radon Transform
Correct X Shift of Confocal Images
Multi Otsu Threshold
Spectral Unmixing of Bioluminescence Signals
Lipschitz Filter
Float Morphology (erode, dilate, open, close)
X_Shifter

Graphics

Arrow
Text Demo
QuickTime Movie Player
3D Surface Plotter
Paint Brush
Resize Canvas
Example Plot
Morph one image to another
Random Ovals
3D Text Demo using Java 2D
Reduce size using averaging
Image Layering Toolbox
Contour Plotter
Animated Sine Wave
Dynamic Profiler
Z-Axis Profiler
Dotted and Dashed Lines
Radial Grid
Interactive 3D Surface Plots
Fractal Generator
Diffusion Limited Aggregate Models
Fractal Growth Models

For instance, we show in this table some of the plugins developed around ImageJ by the scientific community (filters and graphics). The total amount of plugins published in the project website is bigger than 280 and all of them are OSS. Besides, you can get much more plugins in several scientific projects. These plugins are not yet published in the website of the ImageJ project.



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Granulometric Filtering
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Auto Gamma (gamma correction)
Linearize Gel Data
Radon Transform (back projection, sinogram)
Correct X Shift of Confocal Images
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