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Open Source in Imaging Informatics

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The open source community within radiology is a vibrant collection of developers and users working on scores of collaborative projects with the goal of promoting the use of information technology within radiology for education, clinical, and research purposes. This community, which includes many commercial partners, has a rich history in supporting the success of the digital imaging and communication in medicine (DICOM) standard and today is pioneering interoperability limits by embracing the Integrating the Healthcare Enterprise. This article describes only a small portion of the more successful open source applications and is written to help end users see these projects as practical aids for the imaging informaticist and picture archiving and communication system (PACS) administrator.

KEY WORDS: Open source, DICOM, imaging informatics, standards

INTRODUCTION

Imaging informatics is a powerful field representing the intersection of physicians, physicists, and clinical staff with computer scientists and information technology (IT) professionals from across a diverse range of academic, clinical, and corporate settings. The field is challenged to continuously identify, develop, embrace, and promote innovations that have profound effects on the ways in which health care is delivered. The myriad types of interactions, the computational intensity, and the wide variety of applications required for successful imaging informatics practice call for clearly defined and easily implemented standards.

The process of sharing source code and programs has played an important role in the development of the field of imaging informatics. Open source development has been critical in accelerating the adoption of the digital imaging and communication in medicine (DICOM)[1] standard, the de facto global IT standard for medical imaging.[2] Open source applications have become synergistic partners of open standards by providing a powerful means of building reference implementations.[3–7] Some of these applications are of great practical value to picture archiving and communication systems (PACS) administrators in diagnosing integration problems commonly seen in clinical settings.

Open source is an umbrella term—at once a noun and adjective—that describes a development method that allows researchers to exchange algorithms and IT professionals to share tools.[8] This process not only facilitates individual advances but, by pooling resources and freely publishing improvements, results in more rapid consensus development and validation of new tools. Open source communities have been able to utilize the Internet to identify and engage contributors from around the world to effectively distribute efforts to develop advanced and robust information systems. As imaging informatics matures, open source is likely to play an increasingly important role in both basic imaging research and clinical diagnostic and therapeutic practice.

An open source program is one in which the source code to the software application is freely available for distribution along with the program itself. Access to the source code gives the knowledgeable user the ability to create "fixes"

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to the program and make modifications that may be of benefit either in specific circumstances or for general use. More than 190,000 programs are currently hosted by the two major open source repositories at http://sourceforge.net and http://freshmeat.org.

Several of the most successful open source programs in diagnostic imaging are profiled in this special edition of the *Journal of Digital Imaging*. One rationale for this special edition is the growing divide between the technical and end-user perspectives in the medical imaging community. Although the topic of open source development might seem more suited to IT professionals, it is important that all members of our community be at least aware of the potential significance of these powerful tools for continued advancements.

For some imaging department professionals, knowledge about open source is essential. Open source programs and utilities should be essential parts of the PACS administrator's armamentarium for diagnosing problems and maintaining a smoothly running PACS operation. Several platforms are available to enable even those developers without advanced skills to innovate in specific imaging research applications. For any medical professional interested in understanding the growing complexities of DICOM, one of the best approaches is to download and start using open source programs to see exactly what makes DICOM tick.

The central tenet of open source is the free and collaborative exchange of ideas that combine to enhance innovation. Although sometimes depicted as counter to traditional models of proprietary software development, open source has proven to be a successful approach for selling services based on sequentially enhanced versions of the freely available programs. Many commercial vendors in radiology now participate enthusiastically in open source efforts. The distributed software methodology of successful open source applications has also resulted in high quality, as many developers peer review the contributed code. This has been demonstrated to be superior in some cases to commercial software applications.[9,10] This article is intended to provide the reader with an introduction to the ways in which open source has been used in diagnostic imaging and to provide as a ready reference a list of programs that are open source and available for working with DICOM.

THE VALUE OF OPEN SOURCE IN ROUTINE IMAGING

PACS administrators should consider using open source tools for several reasons. Programs in which the users participate as developers are most often powerfully intuitive. Open source development methodology shortcuts the traditional barrier in development with degrees of separation between the users and developers of an application.[11] This observation is reinforced by the fact that systems administration tools that are open source are usually quite competitive with their commercial counterparts.

Another benefit of the open source approach is in circumventing traditional bureaucratic and budgetary restraints. Depending on the specific practice or institution, the process of purchasing new IT tools may be cumbersome and time consuming. Moreover, budgets can be trimmed at the last minute, effectively overturning well-laid planning for new systems. Familiarity with open source resources and the ability to easily integrate these tools not only provides "no-cost" programs, it frees the PACS administrator (in at least this one area) from dependence on the timelined purchase approval process. These benefits extend to the other end of the traditional purchase process: open source tools are available immediately (no ordering or delivery time required), an advantage that can help to avoid slowdowns or hold-ups, for example, in tightly scheduled modality integration projects.

Open source also carries distinct learning curve advantages. The cost of new software applications (not insignificant investments) pales beside the time costs incurred in bringing users up to speed and proficiency. Familiarity with one open source program accelerates the learning curve on all its subsequent iterations. Moreover, open source tools are portable. They can move with the skilled PACS administrator from job silo to job silo within or even across institutions, without the need to negotiate with employers for the purchase of the software platform with which that administrator is most experienced.

Predicting the utility of an untried software tool is not a foolproof science. Not every tool lives up to expectation or advertising. With open source programs, one seldom needs to go all the way back to the metaphorical drawing board to find a

solution or a different tool, and the process does not require either begging for budgetary forgiveness or asking for additional funding.

Finally, an open source community offers an excellent avenue of growth as an imaging professional, even for individuals whose principal interests are not in software development. The collaborative exchange of ideas in an open forum not only helps to "grow" skills on an as-needed basis, but provides a virtual setting in which accumulated expertise results in recognition for some participants as international leaders and experts in their areas.

FROM INNOVATION TO ACCEPTANCE

Before DICOM, one vendor's imaging system—and all of its components—had no way of communicating with other vendors' systems. Each hospital purchased a complete system from a single vendor, with work stations, archive, modalities, and film printers all on an isolated proprietary network. The Radiological Society of North America commissioned two groups to develop DICOM communications tools in the early 1990s as a means to accelerate the adoption of the DICOM standard.

The OFFIS group (Oldenburg, Germany) developed DCMTK, a collection of libraries and applications implementing large parts of the DICOM standard. It includes software for analyzing, constructing, and converting DICOM image files, handling offline media, sending and receiving images over a network connection, and other features.

The Electronic Radiology Lab at the Mallinckrodt Institute of Radiology (St. Louis, MO) originally developed the central test node (CTN) software to support cooperative demonstrations by medical imaging vendors and has been upgraded as imaging technologies and requirements have advanced.

Vendors were allowed to take the source code from both the DCMTK and CTN efforts and implement these in their clinical systems to support the standard. Vendors also found that the source code was particularly useful in understand-

Table 1. DICOM Servers

Server	License/Updaate	Homepage/Description
CTN	License: Public Domain Last update: 2003-03-11	Homepage: http://wuerlim.wustl.edu/DICOM/ctn.html Descriptions from site: "MIR DICOM Central Test Node Software The Central Test Node (CTN) software is a DICOM implementation which was designed to be used at the RSNA annual meetings to foster cooperative demonstrations by the medical imaging vendors. The goal was to provide a centralized implementation that facilitated vendor participation based on the evolving DICOM standard."
Conquest	License: Public Domain Last update: 2007-02-01	Homepage: http://www.xs4all.nl/~ingenium/dicom.html Descriptions from site: "A full featured DICOM server has been developed based on the public domain UCDMC DICOM code. Some possible applications of the Conquest DICOM software are: DICOM training and testing Demonstration image archives Image format conversion from a scanner with DICOM network access DICOM image slide making DICOM image selection and (limited) editing Automatic image forwarding and (de)compression."
DCMTK	License: BSD Last update: 2005-12-20	Homepage: http://dicom.offis.de/dcmtk.php.en Descriptions from site: "DCMTK is a collection of libraries and applications implementing large parts the DICOM standard. It includes software for examining, constructing and converting DICOM image files, handling offline media, sending and receiving images over a network connection, as well as demonstrative image storage and work list servers. DCMTK is is written in a mixture of ANSI C and C++. It comes in complete source code and is made available as "open source" software."
DCM4CHE	License: LGPL Last update: 2007-05-10	Homepage: http://www.dcm4che.org Descriptions from site: "dcm4che is an implementation of DICOM in Java. The sample applications may be useful on its own. It also includes an IHE compliant Image Archive application, based on J2EE."
Dcmrouter	License: Unknown Last update: 2006-11-17	Homepage: http://sourceforge.net/projects/dcmrouter/ Descriptions from site: Dcmrouter is a java-solution of a "Dicom Router", which is able to receive Dicom Objects and transmit them after manipulating with plugins.

ing how DICOM was intended to be implemented and the challenges that would likely be faced in everyday operations. These efforts were successful and were key factors in transforming the medical imaging industry from an ad hoc approach to today's best-of-breed environment. Both DCMTK and CTN remain available today and are used by clinical vendors to implement the DICOM components of their software.

Many software vendors who first perceived open source as a threat to their proprietary offerings have now come to appreciate several advantages that open source can leverage for their companies' continued success. The medical imaging industry has partnered with the open source community in several ways, including but not limited to:

- Reducing support costs: Costs associated with support and maintenance of older code can be a substantial drain on commercial vendors. Open sourcing lowers the support costs of legacy applications and allows commercial developers to focus on adding value instead of patching older software.[12]
- Reducing development costs: Open source software can lower the cost of development by using existing open source programs to add to the features of a vendor's product. This is especially useful in efforts to ensure that new products conform to DICOM and HL7 standards and requirements.
- Adding business advantages: By releasing programs as open source, a commercial vendor can

Table 2. DICOM Tools

Tool	License/Update	Homepage/Description
Dicom Validation Tool Kit	License: LGPL Last update: 2007-03-08	Homepage: http://dvtk.org Descriptions from site: The DVTk project creates different tools that will assist in the development, testing, and servicing of medical interfaces such as DICOM and HL7. These tools provide you with a lot of functionality and capabilities to improve the quality of the interfaces of your products and will assist you in case you have integration problems.
Dicom3tools	License: Unknown Last update: 2004-10-26	Homepage: http://www.dclunie.com/dicom3tools.html Descriptions from site: Tools and libraries for handling offline files of DICOM 3 attributes, and conversion of proprietary formats to DICOM 3. Can handle older American College of Radiology (ACR)/NEMA format data, and some proprietary versions of that such as SPI.
Dicomparser	License: Unknown Last update: 2005-01-19	Homepage: http://sourceforge.net/projects/dicomparser/ Descriptions from site: DICOMParser is a small, lightweight C++ toolkit for reading DICOM format medical image files. It builds on several platforms including Linux, AIX, HP-UX, IRIX, SunOS, Visual C++, Borland C++, and Cygwin. DICOMParser is used in VTK and ITK.
MESA	License: BSD Last update: 2006-04-7	Homepage: http://wuerlim.wustl.edu/mesa/index.html Descriptions from site: As part of the IHE project, the ACC, HIMSS, and RSNA commissioned a set of software tools, which would be used to help participants prepare for demonstrations at the annual meetings. We have coined the term MESA to describe these tools. The purpose of the tools is to provide communication partners, test data, and test plans to allow organizations to provide a baseline level of testing as they implement the IHE Technical Framework. These tools are made available to participants during the period of an IHE demonstration year and are then released into the public domain at the end of that cycle.
openDICOM.NET	License: LGPL Last update: 2007-04-19	Homepage: http://opendicom.sourceforge.net/ Descriptions from site: The openDICOM# Class Libary, main part of the openDICOM.NET project, provides an API to DICOM in C# for Mono and the .NET Framework
PixelMed Java DICOM Toolkit	License: BSD like Last update: 2007-04-04	Homepage: http://pixelmed.com/#PixelMedJavaDICOMToolkit Descriptions from site: "This is a stand-alone DICOM toolkit that implements code for reading and creating DICOM data, DICOM network and file support, a database of DICOM objects, support for display of directories, images, reports and spectra, and DICOM object validation."

Table 3. DICOM Viewers

Viewer	License/Update	Homepage/Description
Aeskulap	License: GPL Last Update: 2006-03-08	Homepage: http://freshmeat.net/projects/aeskulap Descriptions from site: Aeskulap is a medical image viewer. It is able to load a series of special images stored in the DICOM format for review. It is able to query and fetch DICOM images from archive nodes (also called PACS) over the network. The goal of this project is to create a full open source replacement for commercially available DICOM viewers. It is based on gtkmm, glademm, and gconfmm and designed to run under Linux. Ports of these packages are available for different platforms. It should be quite easy to port it to any platform were these packages are available.
Amide	License: GPL Last update: 2006-10-22	Homepage: http://amide.sourceforge.net/index.html Descriptions from site: "AMIDE is a completely free tool for viewing, analyzing, and registering volumetric medical imaging data sets. It's been developed using GTK+/GNOME, and runs on any system that supports the toolkit (Linux, Windows, Mac OS X with fink, etc.)."
ClearCanvas	License: BSD Last Update: 2007-05-18	Homepage: http://clearcanvas.ca Descriptions from site: ClearCanvas Work station is our friendly, easy-to-use DICOM PACS viewer. Because it is built on top of our highly extensible application framework, we expect that it will be appropriate not just for radiologists and clinicians, but also researchers who want to build new, cutting edge tools that can be easily "tried out" in a clinical environment.
EViewBox	License: GPL Last update: 2001-11-18	Homepage: http://sourceforge.net/projects/eviewbox Descriptions from site: "Eviewbox is a java imaging suite, its purpose is to view and spread native DICOM medical images, allowing for 2D and 3 reconstructions. EViewbox applet will allow to see the DICOM images on every platform."
ezDICOM	License: BSD Last update: 2004-12-02	Homepage: http://sourceforge.net/projects/ezdicom/ Descriptions from site: "ezDICOM is a medical viewer for MRI, CT, and ultrasound images. It can read images from Analyze, DICOM, GE Genesis, Interfile, Siemens Magnetom, Siemens Somatom, and NEMA formats. It also includes tools for converting medical images from proprietary format"
ImageJ	License: Public Domain Last update: 2007-05-25	Homepage: http://rsb.info.nih.gov/ij/download.html Descriptions from site: "ImageJ is a public domain Java image processing program inspired by NIH Image for the Macintosh. It runs, either as an online applet or as a downloadable application, on any computer with a Java 1.1 or later virtual machine. Downloadable distributions are available for Windows, Mac OS, Mac OS X and Linux. It can display, edit, analyze, process, save and print 8-bit, 16-bit and 32-bit images. It can read many image formats including TIFF, GIF, JPEG, BMP, DICOM, FITS and "raw. Custom acquisition, analysis and processing plugins can be developed using ImageJ's built in editor and Java compiler. User-written plugins make it possible to solve almost any image processing or analysis problem."
kradview	License: GPL Last update: 2006-03-26	Homepage: http://freshmeat.net/projects/kradview/ Descriptions from site: Kradview is a viewer of images obtained from different sources such as x-ray, NMR, and DICOM-compatible imaging devices. Its aim is to be an easy-to-use DICOM viewer with instant rendering of images, no matter the size and the zoom of the DICOM image. It allows medical professionals to view x-ray images easily.
Medwx	License: Python Software License Last update: 2006-10-17	Homepage: http://sourceforge.net/projects/medwx/ Descriptions from site: Mainly a browser for medical patients documents. For now, it works for displaying radiology images in DICOM format. It supports Query/Retrieve. Build on Python, wxPython and ZODB.
NIH Image	License: Free / Public Domain Last update: 2002-11-19	Homepage: http://rsb.info.nih.gov/nih-image/Default.html Descriptions from site: "NIH Image is a public domain image processing and analysis program for the Macintosh. It was developed at the Research Services Branch (RSB) of the National Institute of Mental Health (NIMH), part of the National Institutes of Health (NIH)."

Table 3. (continued)

Viewer	License/Update	Homepage/Description
Osirix	License: GPL Last update: 2007-04-11	Homepage: http://sourceforge.net/projects/osirix/ Descriptions from site: OsiriX, for the Mac OS X, is an image processing software dedicated to DICOM images (".dcm" / ".DCM" extension) produced by medical equipment (MRI, CT, PET, PET-CT,) and confocal microscopy (LSM and BioRAD-PIC format). It can also read many other file formats: TIFF (8,16, 32 bits), JPEG, PDF, AVI, MPEG, and Quicktime. It is fully compliant with the DICOM standard for image communication and image file formats. OsiriX is able to receive images transferred by DICOM communication protocol from any PACS or medical imaging modality (STORE SCP-Service Class Provider, STORE SCU-Service Class User, and Query/Retrieve).

attract talented developers whose efforts mean that the programs will be more widely used. The company can then sell service and support on these same open source programs.

OPEN SOURCE AS A COMMUNITY EFFORT

The true mark of success of an open source project is seen when it matures into a community. Few open source projects evolve to this level, but the process of evolution itself is an example of collaborative quality control. Internet-based evolution in an open source community has been characterized as a winnowing process. For every 10 people who use an open source program, only one person is likely to submit bug reports or feature requests. For every 10 people who submit bugs, only one person is likely to either submit a fix along with the report or submit a new addition.[13] This winnowing process also tends to provide positive results. Eric S. Raymond, one of the pioneers of open source, is often quoted as saying that "many eyes make bugs shallow."[14] Because of the participatory and highly focused nature of collaborative development, community-based open source projects can rival and, in many cases, be superior to commercial code.

Many community-based open source projects also provide a substantial level of customer support through forums and through iterative, shared documentation on Wikis. Users find answers to common and not-so-common questions by searching the forums for reports from others who have encountered and solved similar problems. One telling metric of the merit of an open source project is the level of activity on its online forums. Vibrant and active forums provide responsive customer support from enthusiastic volunteers. Another way to judge the viability of a program is to determine when the last update was made to the software. Good open source projects update their applications monthly, weekly, or, in some cases, daily. Another key to assessment is that the most vibrant communities are those that include not only developers but nonprogrammers. This mix helps to ensure that the project is not a "developer-only" tool, but one with broader utility and appeal.

The copyright on open source projects is sometimes wryly referred to as a "copyleft" because it serves to remove more restrictions than it imposes on the use of the software. Open source projects are typically based on one of two types of licensing models. The first is derived from the Berkeley Software Distribution (BSD)[15] licensing family of permissive free software licenses, which provide the language and structure needed to allow users to redistribute software and even sell it commercially. The CTN and DCMTK DICOM implementations were released under a BSD-like license, helping the effort to accelerate DICOM adoption. The second derivation is based on the GNU General Public License,[16] which allows free use of the software but requires that any modifications be contributed back to the public domain.

EVALUATION CRITERIA FOR OPEN SOURCE PROJECTS

The biggest challenge for the user who wants to get started in open source—even in the relatively circumscribed area of medical imaging—is in knowing where to begin. Once a potentially useful

project has been identified, the next challenge is in determining whether it is a fully featured program or merely an abandoned collection of code. In our large urban imaging department, we use the following preliminary evaluation criteria when assessing an open source project:

- Web site appearance and documentation. Good documentation is perhaps the best indicator of a truly successful open source project. Paradoxically, documentation is often the last task that developers address. In the best open source efforts, documentation is written not by the core developers

Table 4. Research Oriented Tools in Image Processing

Tool	License/Update	Homepage/Description
AFNI	License: GPL Last update: 2007-05-29	Homepage: http://afni.nimh.nih.gov/afni/ Descriptions from site: "AFNI is a set of C programs for processing, analyzing, and displaying functional MRI (FMRI) data—a technique for mapping human brain activity. It runs on Unix + X11 + Motif systems, including SGI, Solaris, Linux, and Mac OS X. It is available free (in C source code format, and some precompiled binaries) for research purposes."
FSL	License: GPL Last update: 2006-04-01	Homepage: http://www.fmrib.ox.ac.uk/fsl/ Descriptions from site: "FSL is a comprehensive library of functional and structural brain image analysis tools, written mainly by members of the Image Analysis Group, FMRIB, Oxford, UK. FSL runs under Linux, Macos X, Windows XP, SunOS and IRIX and is very easy to install. Most of the tools can be run both from the command line and as GUIs ("point-and-click" graphical user interfaces)."
ImageMagick	License: LGPL Last update: 2007-06-13	Homepage: http://www.imagemagick.org/ Descriptions from site: ImageMagickTM 6.1.3 is a robust collection of tools and libraries to read, write, and manipulate an image in many image formats (over 90 major formats) including popular formats like TIFF, JPEG, PNG, PDF, PhotoCD, and GIF. With ImageMagick you can create images dynamically, making it suitable for Web applications. You can also resize, rotate, sharpen, reduce color, or add special effects to an image or image sequence and save your completed work in the same or different image format. Image processing operations are available from the command line, or from the C, C++, Perl, Java, PHP, Python, or Ruby programming languages. A high-quality 2D renderer is included, which provides a subset of SVG capabilities. ImageMagick's focus is on performance, minimizing bugs, and providing stable APIs and ABIs.
ITK	License: BSD Last update: 2007-06-11	Homepage: http://itk.org/index.htm Descriptions from site: "The National Library of Medicine Insight Segmentation and Registration Toolkit (ITK). ITK is an open source software system to support the Visible Human Project. Currently under active development, ITK employs leading-edge segmentation and registration algorithms in two, three, and more dimensions."
KWWidgets	License: BSD Last update: 2007-06-14	Homepage: http://www.kwwidgets.org Descriptions from site: KWWidgets is a free, cross-platform, and open-license GUI Toolkit. Over a hundred C++ classes have been developed. It is also used by the National Alliance for Medical Image Computing for the 3D Slicer project.
3D Slicer	License: BSD Last Update: 2007-06-05	Homepage: http://www.slicer.org Descriptions from site: Slicer is a "point and click" end-user application. Slicer is used as a vehicle for delivering algorithms to computer scientists, biomedical researchers, and clinical investigators.
VTK	License: Free / Public Domain Last update: 2007-06-11	Homepage: http://www.vtk.org/index.php Descriptions from site: "The Visualization ToolKit (VTK) is an open source, freely available software system for 3D computer graphics, image processing, and visualization used by thousands of researchers and developers around the world. VTK consists of a C++ class library, and several interpreted interface layers including Tcl/Tk, Java, and Python. VTK supports a wide variety of visualization algorithms including scalar, vector, tensor, texture, and volumetric methods; and advanced modeling techniques such as implicit modelling, polygon reduction, mesh smoothing, cutting, contouring, and Delaunay triangulation. VTK has been installed and tested on nearly every Unix-based platform, PCs (Windows 98/ME/NT/2000/XP), and Mac OSX Jaguar or later."
XMedCon	License: LGPL Last update: 2004-11-02	Homepage: http://xmedcon.sourceforge.net/ Descriptions from site: An open source medical image conversion utility and library

Table 5. Teaching Files

File	License/Update	Homepage/Description
Medical Image Resource Center (MIRC)	License: Public Domain Last update: 2007-01-23	Homepage: http://www.rsna.org/mirc/ Descriptions from site: "The MIRC project develops tools to enable the medical imaging community to share images and information for education, research and clinical practice—within an institution and via the Internet. MIRC provides a common index that can be searched using medically relevant criteria. MIRC also offers an authoring tool that makes it easy to create radiology teaching files and other electronic documents in flexible formats with a common underlying structure."

but by individuals with the points of view of users. Documentation begins with the front page of the project Web site, which should be easy to navigate and informative. Mature projects will include screenshots, installation guides, user guides, and separate guides for developers.

– Activity and utilization. The second best indicator of a successful project can be found in the statistics provided by open source repositories like http://Sourceforge.net and http://Freshmeat.net. These sites provide relative activity metrics that indicate how often the project is downloaded, when the developers last updated the code, the number of registered users subscribed to the project, and information about activity on bulletin boards.

– Ease of installation. Although many open source applications are supported on a range of platform operating systems, this does not guarantee that applications will be easy to install or will operate as plug-and-plays. Installation failures are most often the result of a lack of

Table 6. Web-based PACS

PACS	License/Update	Homepage/Description
CDIMEDIC PACS Web	License: GPL Last update: 2003-05-02	Homepage: http://sourceforge.net/projects/cdmedicpacsweb/ Descriptions from site: Full-featured free PACS based on ctn, dcmtk, and mysql, with remote administration using apache mod perl and imaging processing capabilities using ImageMagick , Grevera's dcm2pgm DICOM converter and AFNI, available in Debian packaging format for i386
DIOWave	License: GPL Last update: 2003-05-01	Homepage: http://diowave-vs.sourceforge.net/ Descriptions from site: "DIOWave Visual Storage is a Web-based image display system for medical imaging (DICOM); an ultimately low-cost PACS solution for small to large clinical sites. A user can find and see clinical images by using web browsers with image processing capabilities such as zooming and W/L changing. It doesn't require any plugins and supports various browsers such as Internet Explorer, Netscape and Mozilla. It runs on W2K Server using ASP.NET."
miniwebpacs	License: new Last update: 2004-10-28	Homepage: http://sourceforge.net/projects/miniwebpacs/ Descriptions from site: This project seeks to develop a low-cost system to provide storage, control, and recovery of medical images and information in health care providers of small and medium capacity. Such system is based on the DICOM standard and in the actual WEB technologies.
O3-DPACS	License: GPL Last update: 2007-04-17	Homepage: http://www.o3consortium.eu/ Descriptions from site: Currently, the User Community has O3 installations already active in five Italian regions and in short time also members abroad are adhering. The goal of the Open Three (O3) Consortium is to promote an Integrated Health care Environment for archiving, transmission, exchange, retrieval, and visualization of data, signals, images and reports, in which the three dimensions of the Health Policies—Hospitals, Territory/RHIOs and Home Care/Ambient Assisting Living (AAL)) are linked together.
OpenSourcePACS	License: LGPL Last update: 2005	Homepage: http://www.mii.ucla.edu/index.php/MainSite:OpenSourcePacsHome Descriptions from site: "OpenSourcePACS is a free, open source image referral, archiving, routing, and viewing system."

documentation or inadequate validation tests on a multitude of hardware platforms. Immature open source projects may lack installation instructions, include multiple dependencies that are not packaged together, or require specific versioning of those dependencies. If background investigation, as evidenced by reports of other users, indicates that a program is quite difficult to install, this may be a sign that the project has not matured sufficiently to be a good investment of the user's time.

- Technical support forums. A busy and active support forum for a program is not a sign of a buggy application but of the existence of a large group of enthusiastic users who are helping each other get the most value out of the application. In a truly vital open source community, response times for answers to even the most difficult questions can be quite short. The existence of a frequently updated section on common questions (FAQs) is another sign of an active and successful project community.

OPEN SOURCE PROGRAMS IN DIAGNOSTIC IMAGING

Many freeware viewers have been described elsewhere in the literature[17–19] and are not included in the listing presented here. Many open source projects are likely to be missing from this compilation because no central repository or even a common categorization methodology is available for open source projects. Tables 1, 2, 3, 4, 5 and 6 are divided into categories of DICOM servers, DICOM tools, DICOM viewers, teaching file systems, research oriented tools, and Web-based PACS systems.

CONCLUSION

Open source plays an essential role in the field of imaging informatics, facilitating the spread of beneficial innovations into utilization and practice. The list of projects in imaging informatics summarized here shows the scope, depth, and energy of community innovation in our field. The Internet has enabled an international community of distributed development, connecting disparate professionals in the goal of advancing the state of medicine through IT. Open source tools are pervasive in our field and should be an integral part of every PACS administrator's troubleshooting kit.

The best and most continuously rewarding developments in modern IT seem to draw on community-based efforts. The Society of Imaging Informatics in Medicine and the *Journal of Digital Imaging* have their shared roots in the oldest grassroots-based medical imaging effort: the Radiology Information System Consortium. The open source community is a remarkably rich resource from which imaging professionals across the spectrum of practice and research can derive both the everyday tools and the synergistic strategies that will guide us through a future of rapidly changing technologies and demands.

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