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PACS Workstation Software
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INTRODUCTION

Through advances in technology and developments in the application of Information Technology to radiographic imaging, Picture Archive and Communication Systems (PACS) have become increasingly attractive as the image management solution for radiology departments. Radiographic images in digital form can be acquired from a variety of modalities, stored in an archive and communicated to any required remote location.

The user interaction with a PACS takes place at the workstation. This is commonly a PC connected to the PACS network and running PACS software. Normally after passing any security procedures, which in most cases only involves typing a username and password at the workstation, the user is able to view and manipulate examinations of different patients. Comments and annotations can be added to examinations, and examination reports can be created, edited and viewed.

PACS WORKSTATION TYPES

Traditionally, there have been a number of different PACS workstation types, each dedicated to the task performed at the workstation. For example, a hospital may contain a mix of reporting workstations and review workstations. However, because of the increased processing power of the modern PC, the PACS workstation has become a multifunctional tool. Apart from the need for a high resolution display monitor and video card on a PACS reporting workstation, the remaining hardware making up reporting and review workstations is very similar. A consequence of this trend is that a review workstation on a ward can offer the same functionality that until now has been reserved for radiologists in a reporting environment. Also, because of the development of treatment planning tools, for example orthopaedic templating, a review workstation may now have greater functionality than a reporting workstation.

PACS WORKSTATION SOFTWARE

Development

At present, there are two different routes that a software developer can follow in the production of PACS software. One is an application which is installed on the workstation; the other is a JAVA applet. A JAVA applet is a small program that can be sent to the user's computer with a web page. The web page is viewed in a standard web browser, and the applet which can perform interactive animations, immediate calculations and other simple tasks is displayed in the web page. A combination of application and applet can also be used for different workstations within the same PACS solution, e.g. the application could be installed on a reporting workstation, while a clinician using a PC may use the web browser to view images and reports on the ward.
The main advantage of using a PACS application is that the workstation may continue to be used to view images from local acquisition modalities even if the PACS network stops functioning, subject to local connections to acquisition modalities. Using the JAVA applet, if the web server stops functioning, or the network connection fails, access to the applet and image data may no longer be possible.

However, the JAVA applet can be used on any PC with a standard web browser, at any location, without the need for pre-loading special PACS software. A further advantage of the applet is that upgrades to the software need only be put on the web server, whereas upgrades to the application software may require significant manpower in say a large trust, visiting each workstation and installing the software from local CDs.

An applet and an application are capable of performing similar functional tasks, however most vendors who supply both provide an application for the reporting workstations and a less functional applet for image viewing on wards or clinics unless, for example orthopaedic templating is required.

Common Functionality

Opening examinations

Most of the tasks performed at a PACS workstation will involve viewing images of patient examinations and creating, editing or viewing examination reports. This image and text data is stored on the PACS archive and the location of this information on the archive is stored in a database. The workstation software queries the database depending on criteria defined by the worklist functions (*see below*) or user defined searches. The results are displayed on the workstation as a patient list and the user then selects the patient or examination to view.
On the reporting workstation, most vendors provide worklist functions which simplify the method of opening examinations for reporting. The list contains examinations yet to be reported. The radiologist may filter the list by acquisition modality, examination type or referral type. Less common filtering options are patient type (e.g. paediatric, geriatric) and by priority (set by radiographer or referring clinician). The user can choose the filtering method most appropriate to their role or speciality and normally open examinations for reporting in the order they appear on the list, normally chronological. When the report on an examination is complete, the examination information is automatically removed from the worklist. For each user, default filters to be applied can normally be customised so that no manipulation of the patient list is required before beginning a reporting session.
Occasionally, it may be necessary to view images that are not stored on the PACS archive, for example images stored on floppy disk or CD-ROM. Most workstation software packages allow examinations to be opened from any storage device connected to the workstation. Also, most packages support viewing and manipulating non-DICOM image file types such as "BMP" files and "JPEG" files.

Image manipulation

Once an examination has been opened, there are a number of tools provided by most PACS workstation software for the manipulation of the displayed image. As the displayed image is a copy of the original data stored on the archive, manipulating this image does not affect the original image information. Manipulation of the image is useful as it can allow the user to make more accurate decisions with greater confidence:
"Window width/level" controls the range of image pixel values displayed on the screen. The size of this range is defined by the window width, and the centre of the range is defined by the window level.
"Magnifying tool" creates a small magnifying window on the image. The position of the magnifying window is determined by the mouse position and the size of the window and amount of magnification can normally be varied.
"Pan/Zoom" zooms into the selected image instead of creating a magnifying window. This zoomed image can then be moved around by using the pan tool.
"Toggle overlay" alternately displays and hides patient and examination related information as an overlay on the image.
"Flip/Rotate" allows the currently displayed image to be flipped horizontally or vertically, and rotated clockwise or anticlockwise.

"Toggle annotations" displays and hides user annotations as an overlay on the image.
"Invert Greyscale" swaps light grey shades in the image for dark grey shades, and visa versa.

Measurement

Apart from simply manipulating the display of an image, most PACS software includes tools to make measurements and extract statistical information from the image data. Measurements are normally made by drawing on the image

using the selected measurement tool. These drawings are shown and hidden by selecting the "Toggle annotations" tool and the annotations may normally be saved and recalled at a later date.
"Line tool" measures the distance between two points on the image.
"Elliptical tool" measures the area of a drawn ellipse on the image. Some elliptical tools also display statistical information regarding the pixel values within the drawn ellipse.
"Angle tool" measures the angle between two intersecting lines drawn on the image.
"Pixel or Point tool" displays the x-y position and original greyscale or Hounsfield value of the pixel under the mouse pointer.

Multislice tools

There are a number of tools used specifically to view multislice examinations. Due to the capabilities of current multislice modalities, multislice examinations can now contain large numbers of series each consisting of large numbers of images. Therefore, any tool that can ease the interpretation of these examinations can greatly improve the efficiency of the user.
"Series synchronization" allows multiple series to be synchronized, so that as the user scrolls through the images in one series, the other series auto scrolls. All of the series therefore display images from similar levels in the body.
"Cine" allows Multislice examinations to be viewed as an animation, i.e. the images from a series are scrolled through without any interaction from the user.
Identification and display of key images allows significant images in a series to be flagged for printing or quick future retrieval. The latter allows key images to be retrieved without having to navigate through all the images in a series.

Exporting

As previously discussed, image data viewed at the PACS workstation is a copy of the data stored in the PACS archive. Saving changes to an image does not alter the data in the archive, but saves annotations and comments added by the user. When saving a DICOM image, a copy of the image data is saved using the current window width/level settings as the default settings when the image is next viewed. DICOM images can also be "Sent" to any other workstation connected to the PACS network or burned onto CD for distribution. Non-DICOM "BMP" and "JPEG" images can normally be created from the DICOM image on most PACS workstation software. One other export method available in most PACS software is "Print". This allows examinations to be printed by a DICOM film printer for conventional distribution. It should be noted that restricting the exporting of images from the PACS is crucial to protecting the patient's right to confidentiality. In film based radiology departments the copying and distribution of film is normally controlled. Similar restrictions should also apply to data held on the PACS.

Less-common Functionality

The functionality described above would be found on most PACS workstation software packages. There are also functions which some but not all of the software packages can perform (No single package can perform all of these functions).

Customisation

While using the workstation software, each user can customize a number of display options. The settings for these options can be saved and then become the default settings for that user. Typical examples of the customizable settings are: "Screen layout" which defines the default position and size of the various toolbars and windows on the display monitor; "hanging protocol" which defines the default layout of the images on the display monitor for each type of modality; and "Window width/level" which defines default window width and level settings for each type of modality.

Importing

"Twain acquire" allows request forms or films to be scanned or digitized and saved as a DICOM image file. This function is most useful in a new PACS installation, where historical images on film need to be compared with newly acquired images on the PACS.
"AVI" video files can be imported and viewed using the Multislice cine tool.
"GIF" and "TIFF" image data files can be imported and viewed as if they are DICOM image files.
"Display key prior images" is a time saving tool which automatically opens and displays key images from relevant previous examinations of the current patient. For example, when viewing a chest x-ray belonging to a particular patient, any previous chest examinations of the same patient can automatically be opened by a single mouse click.

Image manipulation

"Region of interest" or "Local window width/level" allows the display of the image pixel values in a user-selected region of the image to be optimized.
"Histogram" is a tool which displays a graph showing the image pixel values along a line drawn on the image by the user.
"Pseudo colour" converts the greyscale values of each pixel to colour, resulting in easier differentiation of structures with low contrast.
Image filters may be applied to the displayed image to aid in diagnosis. Examples of image filters are smooth, sharpen and edge enhancement.
Digital Subtraction Angiography (DSA) may be carried out at the PACS workstation freeing-up the DSA workstation and suite.
"Image merge" allows one image to be overlaid on another for direct comparison of anatomical structures.
"Image crop" removes the area of the image located outside a user selected region.
"Image stitch" allows multiple images to be stitched together to form a larger image.
"Patient anonymization" is used to remove any patient identification information from an examination before exporting the examination for teaching or demonstration purposes.

Measurement

"Calibrate image" is a tool used to calculate the scale of a digitized image, therefore allowing accurate measurements to be made by the measurement tools.
"Cobb angle" is used to evaluate the curvature of the spine in patients with scoliosis. The "Cobb angle" tool measures the angle between two lines drawn on the image, where the intersection between the two lines may occur beyond the edge of the image.
"Rectangle" and "Polygon" tools measure the area of a drawn rectangle or polygon on the image. As with the "Elliptical" tool, some rectangle and polygon tools can display statistical information regarding the pixel values within the drawn shape.
The "Note" tool allows user comments to be added to an examination. The note is displayed as an annotation and is saved when the examination is closed.

Multislice

"Show reference lines" displays the position on the scout image of the cross-sectional images. Normally the first, last and currently displayed cross-sectional images are highlighted.
"3D point locator" shows, for example, the position on a sagittal and coronal images of a user selected point on an axial image.
"Create or remove scout view" is used to create or remove a scout image in a multislice examination.
"Multi-Planar Reconstruction" (MPR) is used to reformat a volumetric data set in any user-defined plane.
"Maximum Intensity Projection" (MIP) is used to reformat projection images of a volumetric data set showing only those voxels with the highest values. The direction of projection can be altered to produce images from any user-defined viewing angle.
"Volume rendering" is a method by which the workstation software is able to generate images of anatomical structures which appear similar to how the eye would view them. The 2D images are generated from an acquired volume of data by simulating the physics of light interaction with the volume.

Exporting

"AVI" and "MPG" video files, as well as "GIF", "TIFF", "PNG" and "Raw" image files are able to be exported. Some PACS workstation software also allows the creation of "HTML" documents and the printing of images onto paper.

Additional functions

"Macro recording" is a very important tool for improving the efficient use of a PACS workstation. A macro is a recording of the user's input to a computer. When a particular combination of tools is often selected and used in the same manner, a macro could replace the user having to repeat the combination every time it is required. Recording a macro involves carrying out the sequence of mouse movements, clicks and keystrokes once, and then assigning the macro's activation to a menu item or button on the software interface. Playing the macro is then achieved simply by selecting the menu item or clicking the button with the mouse pointer. The software then simulates the user's recorded input.

Extended functionality

PACS vendors provide workstation software with some combination of the functions mentioned above. However, a number of vendors are expanding this functionality by including "add-on" tools with their software. These extra tools may be the vendor's own product, or be supplied, via the vendor, by a 3rd party.

Voice recognition

Voice recognition is a software tool for processing human speech. After the user has taught the software their unique accent, pronunciation and inflections, the software is able to recognise the words spoken by the user. The software can then interpret these words as commands, or output the speech as text. In PACS, voice recognition is mainly used in the production of reports. This speech-to-text eliminates the steps of tape dictation and transcription in the conventional production of the report.

Orthopaedic templating

Orthopaedic templating is a method of orthopaedic treatment planning prior to surgery. Suppliers of orthopaedic prosthetics provide template images of their range of products. An orthopaedic surgeon can then overlay these templates onto radiographic images at the workstation, and determine the size and shape of prosthesis to use for that patient. At present, the use of templating is limited to hip replacement surgery; however the same principal could be applied to a number of specialities in the field of prosthetics.

Virtual Endoscopy

Virtual endoscopy is a method of simulating an endoscopic procedure on a volume of data acquired from CT or MRI. The most common type of virtual endoscopy is colonoscopy; however the same technique can be used to view the lumen of any structure within the body. The user first defines the path to be followed along the length of the colon. The software then generates surface shaded or volume rendered images of the colon viewed from a large number of points along the length of the path. Each of the images is a single frame, and when all the frames are viewed in sequence, a "fly-through" animation is produced of the colon. The advantages of virtual endoscopy when compared with conventional endoscopy are well documented. Furthermore, research in this field is increasing the automation of a number of stages in the production of virtual endoscopic examinations.

Computer aided detection or diagnosis

Computer aided detection or diagnosis (CAD) is a tool used to alert the radiologist to potential pathological structures in the image. At present, the most successful use of CAD has been in the detection of suspicious microcalcifications and masses in mammography, however, there have also been a large number of studies investigating the application of CAD in lung CT and virtual endoscopy with varying degrees of success.

Discussion

(i) Functionality
Comparing functionality is a valuable first step in the evaluation of workstation software; however, being able to perform every function does not necessarily make good workstation software. Good PACS software will have a balance between having every conceivable function and having the minimum functions required for basic reporting. The ease with which these functions can be performed should also be taken into consideration. For example, using one vendor's software, different image manipulation tools can be assigned to the right and left mouse buttons independently. Using another vendor's software, the same tools must be selected individually and tasks are performed using the left mouse button only. Although this is a small inconvenience, having to repeat these actions for a large number of patient examinations could result in wasted valuable time. As both vendors may claim similar functionality, this type of observation can only be achieved by using or viewing a demonstration of the software.

(ii) Workstation Interface Design
Similarly, the design of the PACS workstation interface can have a significant impact on the efficient use of the PACS. The design should be intuitive with no repetitive unnecessarily large mouse movements. The majority of PACS software have toolbar buttons which can be used to activate the various tools available within the software. The icons on the toolbar buttons need to be meaningful and memorable (such as the Microsoft© common user access menus) so that the user does not need to reacquaint themselves with the button meanings each time they use the software. The toolbar occupies space on the display area of the workstation monitor, and therefore reduces the available space for the display of images. Between vendors, the toolbar buttons vary in number and size, resulting in a variation in the area of the workstation monitor available for image display. A further consideration is that a large number of vendors continue to display toolbars on the screen even when the related toolbar functions can not be applied to the currently displayed image. For example, when viewing a CR image, the multi-slice tools are often still visible on the display even thought the multi-slice tools can not be applied to CR.

An occasionally encountered problem with the user interface is the displayed size of the menu text. When a high resolution display monitor is attached to the PACS workstation, the largest selectable text size may not always be easily readable. This is often because the menu text size is defined by the operating system text size, and most general purpose operating systems are not designed to be used with very high resolution displays.

When considering the user's interaction with a workstation, it is easy to imagine a radiologist with a headset commanding the software via voice recognition, a joystick controlling window width and level, and a tracker ball and various buttons controlling other tools. However, the end user of PACS software will typically be a medical professional who may not have the time or inclination to use many "gadgets", and it should be remembered that the most common method of interacting with a PC outside of a PACS environment is via a keyboard and mouse. Therefore, familiar interaction with the PACS will increase its acceptability by the user, as well as reduce the need for special accessories. The one exception to this is the PACS workstation in an operating theatre, where various methods of controlling the PACS have been explored with mixed success.

Comparison of Vendor's Software

The following table illustrates the various functions performed by PACS reporting workstation software available in the UK. It should be noted that some of the functionality offered by the vendors is an option supplied through 3rd party software, while some other functionality is supplied as an option to the basic reporting workstation package

PACSnet: Bence-Jones Offices, St George's Hospital, London SW17 0QT
020 8725 3315
www.pacset.org..uk

MHRA: Hannibal House, Elephant & Castle, London SE1 6TQ
020 7273 0000
www.mhra.gov.uk

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	Import Image						Manipulate Image															Measure								Multislice								Export					Extended functions				
VENDOR (Application)	**Search**	**Worklist functions**	**Open local (CD)**	**Twain acquire**	**Open non-DICOM**	**Key prior images**	**Window width/level**	**Magnify**	**Pan/zoom**	**Toggle overlay**	**Toggle annotations**	**Flip/rotate**	**Invert greyscale**	**Local window width/level**	**Histogram**	**Pseudo colour**	**Image filters**	**Digital subtraction angiography**	**Image merge**	**Image crop**	**Image stitch**	**Patient anonymization**	**Line tool**	**Elliptical tool**	**Rectangle / Polygon tool**	**Angle tool**	**Cobb angle**	**Pixel / Point tool**	**Note tool**	**Calibrate image**	**Series synchronization**	**Cine tool**	**Show reference lines**	**3D point locator**	**Create / remove scout image**	**Multi-planar reconstruction**	**Maximum intensity projection**	**Volume rendering**	**Image send**	**Burn CD**	**Save non-DICOM**	**Film print**	**Paper print**	**Record macro**	**Voice recognition**	**Orthopaedic templating**	**Virtual endoscopy**	**Computer aided detection/diagnosis**
AGFA (Impax / Web 1000)	■	■	■	■		■	■	■	■	■	■	■	■	■		■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Cerner	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
ComMedica (Pirilis)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■					■	■	■	■		■	■		■	■	■	■	■	■	■	■	■	■	■	■	■		■			
Ferrania (Lifeweb)	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■			
Fuji (Synapse)	■	■	■			■	■	■	■	■	■	■	■	■		■	■					■	■	■	■	■	■	■	■	■	■	■	■					■	■	■	■	■		■			
GE (Centricity Pathspeed)	■	■				■	■	■	■	■	■	■	■	■		■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■		
Kodak (AutoRad)	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■		■		■
McKesson (Ultrapacx)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Philips (Easy vision / Web)	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Pukka-J (DICOM Explorer)	■		■	■	■	■	■	■	■	■	■	■	■	■		■	■	■		■		■	■	■			■	■		■	■		■	■	■	■		■	■	■	■					
Rogan-Delft (Hyperview)	■	■	■	■			■	■	■	■	■	■	■				■						■	■	■	■		■	■	■	■	■						■	■	■	■	■			■		
Sectra (IDS5)	■	■	■	■		■	■	■	■	■	■	■	■		■	■	■		■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■
Siemens (Magic view)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
storCOMM (MedView)	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■
Torex (Sectra IDS5)	■	■	■	■		■	■	■	■	■	■	■	■		■	■	■		■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■
Xograph (Bluerose/eFilm)	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■				■	■		■		■	■	■	■	■	■	■		■	■	■	■	■	■	■	■			■		

Web Sites:

AGFA (Impax / Web 1000) http://www.agfa.com/healthcare/

Cerner http://www.cerner.com

ComMedica (Pirilis) http://www.commedica.com/

Ferrania (Lifeweb) http://www.ferraniait.com

Fuji (Synapse) http://www.fujimed.com

GE (Centricity Pathspeed) http://www.gemedicalsystems.com/

Kodak (AutoRad) http://www.kodak.com/global/en/health/

McKesson (Ultrapacx) http://www.mckesson.com/index.php

Philips (Easy vision / Web) http://www.medical.philips.com

Pukka-J (DICOM Explorer) http://www.pukka-j.com

Rogan-Delft (Hyperview) http://www.rogan-medical.com

Sectra (IDS5) http://www.sectra.se

Siemens (Magic view) http://www.smed.com

storCOMM (MedView) http://www.storcomm.com

Torex (Sectra IDS5) http://www.torexhealth.co.uk

Xograph (Bluerose/eFilm) http://www.xograph.com/Medical/