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Determining Appropriate Window and Level Settings for Displaying DICOM Images in a Desktop Publishing Format

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Abstract

When harvesting images from a Picture Archiving and Communication System (PACS), window and level settings continue to present a major obstacle for the conversion of images from the Digital Imaging and Communications in Medicine (DICOM) standard file format to the Joint Photographic Experts Group (JPEG) image format, a desktop publishing format. Evaluation of the window and level values in the DICOM header demonstrated that they cannot be relied upon for generation of useful JPEG images for key image selection. An algorithm was developed to automatically calculate window and level settings for Magnetic Resonance (MR) images. As images are received by a vendor-neutral digital teaching file server, pixel data is read and a histogram of the grayscale values is generated. A portion of the grayscale values are then used to calculate the appropriate window and level settings for image conversion, allowing exported series to be displayed in JPEG format. The algorithm was evaluated and found to be effective for appropriate window and level calculation for key image selection.

Keywords:

radiographic image enhancement, data display, radiology information systems

Introduction

Window and level settings are a major obstacle in exporting Digital Imaging and Communications in Medicine (DICOM) images from a Picture Archiving and Communication System (PACS) in desktop publishing format.[1] In a vendor-neutral environment, a digital teaching file (DTF) has limited ability to retrieve image metadata without requiring direct access to PACS or without receiving specific information from PACS.[2] Therefore it must rely on the metadata available in the image DICOM header. The window and level values contained in the DICOM header are assigned at the point of acquisition and are rarely subject to verification by the radiology technician. In addition, these values are not overwritten by the last viewed or optimum window and level settings applied by the radiologist at the PACS workstation. The DICOM header window and level values were evaluated for their reliability to generate identifiable JPEG images.

An algorithm has been developed to automatically calculate appropriate window and level settings for initial DICOM-to-JPEG conversion. It solves the window and level problem for conversion of Magnetic Resonance (MR) DICOM images to JPEG file format and allows for efficient key image selection without requiring user interaction.

This manuscript describes the innovative integration of open source technology and information management in solving the window and level problem encountered in the development of a vendor-neutral DTF based on ideal characteristics.[3] It outlines the obstacle of window and level settings in exporting MR DICOM images from PACS and the automatic window and level calculation algorithm as a proposed solution.

A word about window and level settings

An important aspect of medical imaging is the ability to manipulate the manner in which images are presented on the PACS workstation screen. In a digital format, the spatial resolution of an image is based on the number of pixels in each row and column (i.e., 128 x 128 or 512 x 512). Each pixel contains information regarding the color attribute and intensity of a specific location on the image. The collection of this information is the pixel data, which is referred to as contrast resolution. The range of grayscale values for typical medical images often far exceeds that which can be perceived by the human eye. For example, a Computed Tomography (CT) image may contain grayscale values from -1000 to +3000, defined as Hounsfield units (HU), that are physical representations of the density of the body part imaged (where 1 unit = 1/10 of 1% of the density of H_20 and H_20 density is set equal to 0 HU). MR images are also on a 12-bit or 4096 unit scale, however, the pixel values have no specific physical representation, and therefore are relative and unpredictable.[1] Although MR image pixel data may represent up to 4096 unique shades of gray, the human eye can only process ~256 grayscale variations.[4]

Manipulation of image presentation is necessary to solve the grayscale limitations of the human eye. In addition, visualization of specific tissue types or anatomical locations requires presentation of the image utilizing only a portion of the total grayscale range. Therefore, DICOM images employ settings to limit presentation of the image to only display the pixels within a more narrow range (window width or "window") with its midpoint applied at a specific location (window center or "level") within the total range of values. In the CT example above, a typical setting for appropriate demonstration of brain tissue is a window of 100 applied at a level of 50 resulting in an image with 256 shades of gray that represent 0 to 100 HU. "Windowing" and "leveling" an image is particularly important for display of the correct diagnostic and educational focus. It also plays an essential role for correct conversion from DICOM to another image file format.[5]

Materials and methods

DICOM header evaluation

During a 6 month testing period, 116 MR studies were sent from PACS to the Radiology Interesting Case Server (RadICS), a vendor-neutral DTF, by radiologists for the purpose of creating interesting cases.[2] The DICOM images from these studies were converted to JPEG files using the DICOM-specific WindowCenter and WindowWidth values from each DICOM header. One study was excluded because it did not contain physical body parts, but rather showed lines and graphs (a quality control study). Image studies were scored "-" if they were predominantly white or black and unidentifiable; otherwise they were scored "+". Evaluation of the included 115 studies (comprised of 778 total series) was conducted by the author (AK).

Automatic window and level calculator

In RadICS, the image server manages the DICOM Receive and DICOM-to-JPEG conversion process.[2] A DICOM Storage Server Class Provider (SCP), from the open source OFFIS DCMTK, handles all incoming DICOM files and moves them to a temporary directory.[6] A PERL script constantly monitors the temporary directory and the presence of a DICOM file initiates the rest of the image server processes. The image server parses the DICOM header using the OFFIS DCMTK and specific data is retrieved. The automatic window and level calculator (AWLC) is called on to determine appropriate window and level settings. These window and level settings are automatically communicated to the PERL script and are passed as parameters to the OFFIS DCMTK to generate new full-size and thumbnail JPEG files. Finally, the original DICOM and newly generated JPEG files are moved to the temporary file storage on the server. At this point the JPEG images are available for key image selection in the RadICS web application.[2]

The AWLC was built using the C++ programming language and uses the automatic window and level calculation algorithm. The algorithm follows a 5-step process: (1) read the image pixel data, (2) generate grayscale histogram, (3) exclude extreme values, (4) calculate median and standard deviation, and (5) calculate window and level settings.

The algorithm begins by reading the pixel data of the MR image. The BitsAllocated, BitsStored, HighBit and PixelRepresentation of the image, as retrieved from the DICOM header are required to read the pixel data. Once read, the pixels are grouped according to their grayscale value, the sum total of pixels per value is calculated, and a histogram is generated. Figure 1 illustrates the histogram. Large spike in the low values of the historgram corresponds to the black pixels surrounding the body part. The bottom fifteen percent (line #1) and top fifteen percent (line #2) of the grayscale range are excluded to account for the large number of black and white pixels in the image. The median and standard deviation of the remaining values are calculated. The median (line #3) is used as the level and a multiple of the standard deviation (line #4) is used as the window for the DICOM-to-JPEG conversion. For MR images with a pixel value range greater than 1000, the standard deviation is multiplied by four. For MR images with a pixel value range less than 1000, the standard deviation is multiplied by six. The fifteen percent exclusion threshold and the 1000 pixel value range threshold were determined empirically.

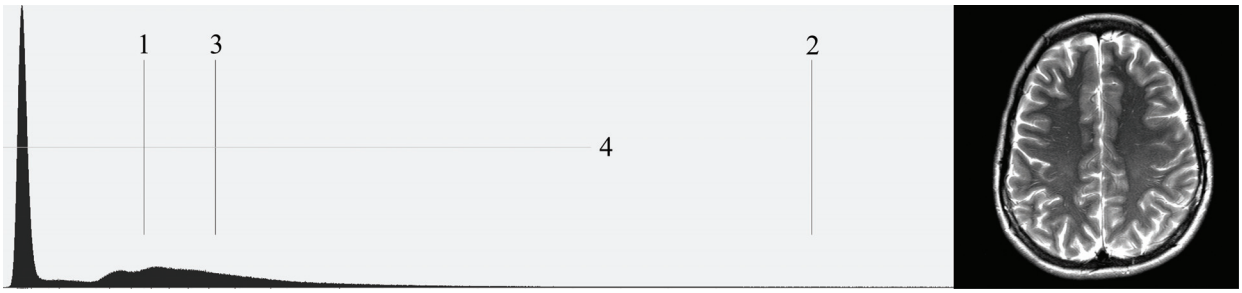

Figure 1 – Grayscale histogram (left) of a Magnetic Resonance (MR) image (right)

Algorithm evaluation

The algorithm was tested on 75 MR images: 25 each of abdomen, brain, and head and neck images. Two Certificate of Added Qualifications (CAQ) board certified radiologists (DEA and RHW) evaluated the automatic window and level calculation algorithm for its ability to generate JPEG images with appropriate window and level settings for key image selection. In addition, they evaluated the similarity between the JPEG image using optimum window and level settings, as defined by the evaluators, with the JPEG image generated using the automatically calculated window and level settings. They evaluated images within their area of expertise. The following evaluation procedure was used. First, a web application was developed to randomly select one MR image at a time from studies already sent to RadICS. The image then was displayed in an open-source, web-based Java DICOM viewer, obtained from the Nagoya Institute of Technology.[7] The evaluators made appropriate window and level changes to achieve optimum settings. At this point, the evaluators were blind to the automatically calculated image. After clicking the done button, the user-defined settings were used to convert the DICOM image to JPEG file format. In addition, a second DICOM-to-JPEG conversion took place using the window and level settings that were automatically calculated via the algorithm. The evaluators were then presented with both JPEG images, side-by-side on the same webpage, and were asked to score the following two comments: (1) The automatically calculated image is appropriate for Key Image Identification; (2) The automatically calculated image is identical to the optimal image (comparing w/l settings). The five possible responses are: (1) Strongly Disagree, (2) Somewhat Disagree, (3) Undecided, (4) Somewhat Agree, and (5) Strongly Agree.[8] Figure 2 is an example of the webpage presented to the evaluators. Scores were tallied for each comment.

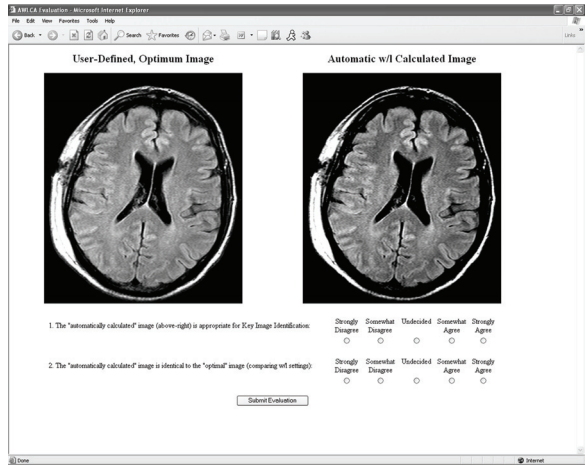

Figure 2 - Example evaluation webpage

Results

DICOM header evaluation

Evaluation of the window and level values in the image DICOM header found 18/115 (15.65%) of studies to be predominantly black or white and therefore unidentifiable.

Algorithm evaluation

Evaluation of the algorithm results in 25/25 (100%) of abdominal MR images, 24/25 (96%) of brain MR images, and 20/25 (80%) of head and neck MR images recorded as appropriate for key image selection. One head and neck MR image was recorded as undecided and the rest were recorded as inappropriate for key image selection. Overall, 69/75 (92%) of the study MR images were thought to be appropriate for key image selection, while 5/75 (6.67%)

Table 1 – Evaluation of the Automatic Window and Level Calculator

			5 Strongly Agree	4 Somewhat Agree	3 Undecided	2 Somewhat Disagree	1 Strongly Disagree
Appropriateness for KIS	AVG	N					
MR Abdomen	5.00	25	25	0	0	0	0
MR Brain	4.72	25	20	4	0	1	0
MR Head and Neck	4.36	25	19	1	1	3	1
Total	**4.69**	**75**	**64**	**5**	**1**	**4**	**1**
Similarity Comparison	AVG	N					
MR Abdomen	4.48	25	15	8	1	1	0
MR Brain	3.80	25	9	9	0	7	0
MR Head and Neck	3.52	25	8	8	0	7	2
Total	**3.93**	**75**	**32**	**25**	**1**	**15**	**2**

were thought to be inappropriate for key image selection and 1 was undecided (Table 1).

In addition, although not a goal of the algorithm, it was found that 23/25 (92%) of automatically calculated abdominal MR images, 18/25 (72%) of automatically calculated brain MR images, and 16/25 (64%) of automatically calculated head and neck MR images were scored as strongly agree or somewhat agree to being identical to their associated user-defined optimum images. One abdomen MR image was recorded as undecided and the rest were not considered identical. Overall, 57/75 (76%) of the study MR images were scored as strongly agree or somewhat agree to being identical to their associated user-defined optimum image, while 17/75 (22.67%) were not considered identical and 1 was undecided.

Discussion

The purpose of this project was to evaluate the reliability of DICOM header window and level values for MR and develop an algorithm to automatically calculate appropriate window and level settings for DICOM-to-JPEG image conversion in a vendor-neutral environment. This is the first automatic window and level calculator seamlessly integrated into the harvesting function of a radiology teaching file reported in the literature. Based on the results of the DICOM header evaluation, the window and level values in the MR DICOM header are unreliable. Therefore, this calculator provides the much needed ability to automatically process MR images into a desktop publishing format.

The algorithm was found effective for appropriate window and level assignment for DICOM-to-JPEG image conversion of MR images. The results demonstrate that these JPEG images are appropriate for selection of key images for case creation. The automatic window and level calculator was successfully implemented in RadICS which is in use at a large academic radiology department.[2]

Even though our objective was to generate JPEG images appropriate for key image selection, as a side note, the authors were interested in the degree of similarity between the automatically calculated JPEG image and a user-defined optimum JPEG image. The results demonstrate that a majority of the calculated images appeared identical to their associated optimum images. Although 22.67% of the images were not identical, the fact that 92% of the images were appropriate for key image selection demonstrates that the objective was met.

The algorithm was designed and tested specifically on MR studies. This modality was selected for its high degree of variable window and level settings from one image to the next and the inability to apply standard, pre-set window and level settings to the study as a whole, such as is possible with CT studies.

In reviewing the results, it is noted that six images scored a three or lower for the appropriateness for key image selection comment. Of these six images, one was in the MR brain group and the other five were in the MR head and neck group. Further evaluation of these images revealed that the one MR brain image was a scout image and not a diagnostic image. In addition, of the head and neck images, one contained a ferromagnetic artifact and a large amount of subcutaneous fat, and the other images were inhomogeneous MRI fields with fat saturation technique and contained areas of loss of fat saturation. A larger variability of calculated window and level settings in MR head and neck images is expected due to the diverse intensity of signals acquired. Also, when selecting a key image for a teaching file from a soft tissue neck MRI study, the ideal window and level setting for the entire image may be significantly different from the perfect window and level setting to best demonstrate a lesion, due to the extreme contrast differentiation between the extracranial head and neck fat, soft tissues, and the pathology of interest, such as a focal soft tissue mass. These factors likely affected the accuracy of the window and level calculation.

The automatic window and level calculation algorithm was designed and developed based on a training set of MR abdominal and MR brain studies. Thus, it is not surprising that it performed well during evaluation in those image groups. The results obtained from the MR head and neck group demonstrates that the algorithm can be efficiently generalized to MR images of other anatomical locations.

While the algorithm has been shown effective in MR images, formal evaluation should be completed to measure the generalizability for use with other image modalities. We anticipate that more sophisticated methods could address other modalities as well as the individual characteristics of images with different educational, anatomical, and diagnostic foci. The empirical exclusion threshold and pixel range cutoff could also be refined by expanding the test set used in their creation. Despite the limitations of the algorithm, it specifically addresses the problem of unreliable DICOM header data in MR images and could be adapted for use in applications other than DTF such as upon post-acquisition arrival of studies to PACS.

Incorporation of the automatic window and level calculator in the RadICS image server provides a fully automated solution for harvesting key MR images into a DTF. Once an interesting study is sent to RadICS, appropriate window and level settings are automatically calculated, and the images are automatically processed and made available for key image selection. Therefore, there is no disruption in clinical workflow.[2]

Conclusion

With the integration of the automatic window and level calculator in RadICS, users can efficiently send MR studies from PACS and access the images in desktop publishing format from a workstation with access behind the radiology department PACS firewall. All processes from the DICOM Receive to web-presentation of JPEG images are automated, enabling the flexibility of sending studies and creating interesting cases at the clinician's leisure.[2] The method described overcomes the obstacle of window and level settings for appropriate DICOM-to-JPEG conversion, without requiring user interaction.

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