Automatic Adjustment of Contrast and Brightness of Magnetic Resonance Images

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Two statistics of the magnetic resonance (MR) image, the median and the standard deviation of the values of the significant pixels, can be used along with the type of image to adjust the contrast and brightness of the image (ie, to "window" it) automatically and robustly. The essential parts of this approach to automatic windowing are (1) avoidance of irrelevant pixels, (2) identification of the type of MR image from information stored in the image header, and (3) use of algorithms for the maximum and minimum values that reflect the preference of the intended viewer using a specific monitor and ambient lighting conditions for the different types of images. An evaluation in thirteen clinical studies yielded 91.5% (2312/2526) images requiring no further adjustment and the remaining 8.5% (214/2526) being improved by further adjustment.

KEY WORDS: Brightness adjustment, contrast adjustment, windowing, automatic windowing.

THE PROCESS OF adjusting the brightness and contrast of a nuclear magnetic resonance image (MRI) is difficult to automate. This adjustment, commonly called "windowing," is done inadequately by many older MR imagers. Automatic windowing is also an essential feature of many efforts to achieve a filmless radiology department.

A simplistic approach to automatic windowing is to determine the minimum and maximum pixel intensities of each image and to map those values to the values of a linear gray scale (typically 0 to 255 for an 8-bit display) in a linear fashion. This method is inadequate for MRI for several reasons. In some MR images, the tissues of interest occupy only a portion of the dynamic range of the image pixel values. The preferred windowing would be to expand the contrast of the tissues of interest while compressing the contrast of those that are not interesting. There are also problems with artifacts in MR images that may lie outside of the important region of the image, but may contribute very bright pixels that confound the simplistic windowing scheme.

The approach that is described here recognizes that different types of MR images need to be windowed differently. Thus, it extracts information from the image header that it uses to determine the type of the image. It determines the actual field of view of the image (eg, square or rectangular) from the header to avoid pixels at the edge of the field of view that are most likely to contain bright artifacts. It ignores pixels that have values lying below a threshold intensity that depends on the type of image being processed. It computes two statistics of the distribution of the values of the remaining pixels: the median and the standard deviation. Finally, it looks up the correct windowing algorithm, which depends on the specific image type and on the preferences of the viewer for whom the image is being prepared, computes the brightness and contrast, and prepares a new image file containing the windowed image.

Other methods such as histogram equalization[1] have been suggested. That approach was not used in order to preserve the gray-scale relationships within the image and to approximate more nearly the filmed images from the MR imagers. Another approach might be to analyze the shape of the histogram of the image and to derive windowing information from its features. The approach described here was implemented first because of its relative simplicity and has been found to be entirely adequate in its performance.

MATERIALS AND METHODS

So far, this method has been developed for routine head MRI's and for magnetic resonance angiography (MRA). In the development phase, ten patient studies were evaluated from either of two 1.5T MR imagers (Magnetom 63SP, Siemens Medical Systems, Iselin, NJ). The data were transferred to a Sun-4/470VX workstation (Sun Microsystems, Mountain View, CA) using the network file system protocol and application software written by the author. Initially the images were categorized by type: spin density,

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Supported by a grant from Siemens Medical Systems, Inc.

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0897-1889/94/0702-0001$3.00/0

T_1-weighted (T_1), T_2-weighted (T_2), scout view, raw MRA (MRA), and maximum intensity projected MRA. The rules for determining type are given in Table 1. The images were also categorized by orientation: transverse, sagittal, or coronal. Each image was converted to Sun's Visualization File Format for viewing with Sun Vision software (Sun Microsystem). Each image was individually windowed. The maximum and minimum values of the adjusted window were recorded along with a number of statistics of the pixel values: mean, median, mode, standard deviation, maximum, and minimum. Various combinations of the pixel statistics were analyzed for their abilities to predict the windowing settings using SigmaPlot software (Jandel Scientific, Corte Madera, CA).

A series, containing thirteen patient studies, including several abnormalities, was then evaluated. These data were originally acquired for another purpose and include very rapidly acquired gradient echo images with parameters distinctly different from those in the training set. The algorithm classified these images as "scout" images and processed them anyway. The images were composed into panels of six, somewhat in the manner of a sheet of film. Each panel was displayed and each image within the panel was described as "good," meaning that every important feature was clearly visible without any further brightness or contrast adjustment, "adequate," meaning that the bulk of the information was clearly visible, but windowing improved the display, or "inadequate," meaning that important features were not visible.

RESULTS

The adjustment rules for different contrast types are shown in Table 2. These rules were chosen from among the many possible combinations of image statistics for two reasons; they were the most accurate over the training set of ten patients and they were the simplest.

The results for the thirteen patients are summarized by contrast type in Table 3. 91.5% (2313/2526) were "good" and 8.5% were "adequate."

Table 1. Rules for Determining Which Algorithm to Employ to Window an Image

Acquisition Type	Conditions (time in ms)	→	Contrast Type
MRA			Raw MRA
FISP3D or FLASH3D	$\alpha < 40°$ and $T_R < 80$		Raw MRA
Processed MRA			Processed MRA
Spin echo or default	$T_R > 1{,}000$ and $T_E > 40$		T_2-weighted
Spin echo or default	$T_R > 1{,}000$ and $T_E \le 40$		SD-weighted
Spin echo or default	$T_R < 400$		Scout
Spin echo or default	$400 \le T_R < 1{,}000$		T_1-weighted

Acquisition type and imaging parameters are deduced from information in header of image file.

Table 2. The Algorithms Applied to Various Types of Images

Contrast Type	Orientation	Minimum	Maximum
Raw MRA	All	0	$1.57M \pm 2.456\sigma$
Processed MRA	All	0	$2.3M$
Scout	All	0	$2.0M$
Spin density	Transverse	$0.762M - 0.536\sigma$	$0.787M + 1.918\sigma$
T_1	Transverse	0	$1.540M$
T_1	Sagittal	0	$1.517M$
T_1	Coronal	0	$1.473M$
T_2	Transverse	0	$2.3M$

M, median value; σ, standard deviation.

DISCUSSION

The development of this method was motivated by the design of a workstation that would access MR images with little or no user attention to details like windowing. The automatic windowing information stored in the image header proved to be inadequate for this purpose. Generally speaking, every study processed has been of satisfactory quality. The merely "adequate" images in the study fall into two categories. One is the fast gradient echo images that had poor contrast initially. In five of the studies, additional windowing improved them. The other category of less than good images contained T_1- and a few T_2-weighted images from a patient with a very bright tumor and another very lean patient in which a few of the post-Gadolinium images had white matter that was too bright. The patient with the very bright tumor was interesting in that the normal brain tissues were of the desired brightness. This suggests that when certain types of abnormality

Table 3. Results of Evaluating the Algorithm in Thirteen Patient Studies

Contrast Type	Good	Adequate	Inadequate
Scout	338	0	0
Fast GE	256	160	0
MIP	60	0	0
T_1	1142	52	0
T_2	257	2	0
Spin density	259	0	0

The number of images, of which there were as many as six on a panel, that were judged to be of each of the three categories of quality. Scout views and raw MRA are combined. The fast gradient echo images are isolated from other scout views.

are expected, a second set of data should be prepared using parameters optimized for the abnormality.

There are only two examples where the method has produced results that might be improved. In maximum intensity projections of MRA studies with an unusually large magnification, the number of pixels containing vessels is much larger than in the images on which the algorithm was developed and the vessels appear to be too bright. In T_1-weighted transverse images of the brain stem, the ratio of fat pixels to brain pixels is dramatically higher than in most transverse levels, and the brain tissues sometimes appear too dark. Neither of these effects is extreme.

The slice-to-slice variation in intensity in these data is completely compensated for by this method, yielding panels of images with no discernible differences in contrast or brightness.

Further investigation of this method should include assessing the variability among observers. This might provide default settings that would be acceptable to the majority of users who have not established personal preferences.

CONCLUSION

This method is very robust in practice and is an attractive alternative to approaches that rely on the pixels of extreme value to define the dynamic range of the displayed image. Although the evaluation presented here is preliminary, a prospective study of greater scope is justified by the encouraging results.

ACKNOWLEDGMENT

The author thanks the technical staff of the MRI Service, the Department of Radiology at The Methodist Hospital, Houston, TX. This work benefited from insightful discussions with David E. King, MD.

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