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A Review On MR Image Intensity Standardization Methods

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Abstract:

The lack of a standard image intensity scale in MRI causes many difficulties in image display and analysis. The intensity of similar anatomical tissues is often different because of the acquisition process. Different approaches dealing with this problem were proposed recently. This paper describes and compares three state-of-the-art standardization methods regarding speed, applicability and accuracy parameters.

Key woreds: *Magnetic resonance imaging, Intensity correction, Histogram, Image registration*

1.Introduction

Magnetic resonance imaging (MRI) has revolutionized radiological imaging of the internal structures of the human body. It has the advantage of being noninvasive, with no known health hazards. A variety of MRI protocols are available with or without the use of contrast agents. These protocols allow the setting up of different contrasts among the different tissues within the same organ system. Unfortunately, one of the major difficulties with MRI techniques has been that intensities do not have a fixed meaning, not even within the same protocol, for the same body region, for images obtained on the same scanner, for the same patient. This implies that MR images cannot be displayed at preset windows; one has to often adjust the window settings per case. The lack of a meaning for intensities also poses problems in following image processing, analysis, segmentation and registration methods relying on intensity similarity. [1]

MRI is the gold standard modality for exploring the brain on its anatomical and pathological sides. For the study of brain pathologies, some quantitative measurements like volume measurement or tissue atrophy are needed. These studies rely on T1 -MRI since this modality reveals brain tissues with more contrast and accuracy than any other kind of brain imagery. For this analysis, computer vision tasks are involved: segmentation, classification, rigid and non-rigid registration, etc. Databases of MR images tend to grow largely but the luminance of the images cannot be directly compared since the acquisition is different. It is necessary to correct for intensity differences between MR acquisitions in order to optimally use large databases. [2] This paper will first give a brief overview of the intensity standardization method described in Nyul et al. [1] that discuss 1-d histogram based approach which matches landmarks on histograms. Further a method described in Hellier et al [2] is discussed which is based on histogram estimation using Gaussian mixtures. Lastly, method described in Jager et al. [3] is described which basically performs a registration of joint histograms.

2.Methods

2.1.Landmark-Based Mri Scale Standardization

The method described in this paper [1] offers a simple way of transforming the images nonlinearly so that there is a significant gain in similarity of the resulting images. It is based on transforming the intensity histogram of each given volume image into a ‘‘standard’’ histogram. This is achieved in two steps—a training step that is executed

only once for a given protocol and body region and a transformation step that is executed for each given volume image. In the training step, a set of volume images of the same body region and protocol corresponding to a population of patients is given as input. The parameters (landmarks) of a ‘‘standard’’ histogram are estimated from these image data. This step needs to be executed only once for a given protocol and body region. In the transformation step, any given volume image acquired as per the protocol and for the body region utilized in the training step is transformed so that its histogram parameters match those of the standard histogram. In this fashion, every patient volume image histogram is deformed to match it with the standard histogram. This step is image-dependent and needs to be executed for each given volume image. This step usually results in a nonlinear intensity transformation for the given image. However, the relationship between tissue intensities is maintained and intensity comparisons can be made using the standardized images. [4]

The preliminary studies performed in this paper indicate that image analysis and tissue segmentation methods are considerably improved in terms of their constancy of parameter settings and their degree of automation. With standardization, numerical meaning is achieved and, hence, numerical diagnosis and study of diseases may become possible.

2.2.Mri Intensity Correction Using Mixture Mapping

This paper [2] proposes a new method to correct for intensity differences between different MR acquisitions. The method basically consists estimating a mixture of Gaussian that approximates the intensity histogram and computing the parametric intensity correction function f that aligns the mean intensity of anatomical tissues. This is done by matching intensities of head specific anatomical tissue classes. Five main classes of brain are used for the same: background, cerebrospinal fluid (CSF), gray matter (GM), white matter (WM) and a mixture of fat and muscle. In the first step the histograms from a source and a target data set, i.e. two 3D images, are approximated by a Gaussian mixture. Each tissue class k is modeled by a Gaussian probability density function which has a mean μk that is approximated using the Expectation-Maximization (EM) algorithm. In the second step a polynomial correction function fp of order p is used to interpolate the correction of the intensities smoothly:

$$f^p(x) = \sum_{i=0}^{i=p} \theta^i \; x^i \qquad (1)$$

By minimizing the following cost function, the coefficients θi are obtained where μj and υj are the means of the reference template image respectively.

$$\sum_{j=1}^{n}\left(f^{p}(\mu_j) - v_j\right)^2 \qquad (2)$$

This correction scheme has proved to be stable and robust, as well as necessary to perform successfully a non-rigid registration between MR images of different subjects. This correction scheme is simple and may be applied to other contexts than medical imaging. This is particularly needed when the illumination conditions vary in an image sequence and also when the same scene is viewed from different viewpoints.

3.Mri Intensity Standardization By Non- Rigid Registration Of Joint Histograms

The idea proposed in this paper [3] is that normalization can be achieved by finding a deformation of the joint histograms of two sets of images with respect to a certain distance measure. Each of these histograms is at least two dimensional and contains the intensity information of two or more MRI sequences (e.g. T1 or T2 weighted images). If the probability density functions are considered as images, the normalization can be treated as a registration problem. The resulting non-linear correction function is used to adjust the image intensities of the MRI image series. In order to evaluate the intensity standardization the mean distance of the reference and the template volumes of one patient were chosen. Hence a good standardization result has a much smaller bias between the reference and the corrected than the unprocessed images. Furthermore, the variance of both distances is given by:

$$\mu = \frac{1}{N}\sum_i (x_i - y_i) \qquad (3)$$

$$\sigma^2 = \frac{1}{N}\sum_i (x_i - y_i - \mu)^2 \qquad (4)$$

With N being the number of used voxels, x_i being a voxel in the template and y_i a corresponding voxel in the reference volume. However, the evaluation method has the drawback, that real patient data with evolving structures was used and thus the anatomy of the brain slightly changed. The lesions were removed by a segmentation step beforehand.

This nonrigid registration of joint probability densities scheme is independent of the application, protocol, and region of interest and even of the acquisition modality. Even this method is a reliable way to adjust image statistics of multiple series of MRI images.

However, the results have to be verified in a broader range and evaluated for different body regions as well.

3.Comparison Between Methods

The discussed three methods are compared for speed, applicability and accuracy where applicability means that the algorithm can be easily adapted to different regions of the body. Accuracy refers to robustness and improvement of the image quality. The results of comparison are shown in Table 1.

Method	Speed	Applicability	Accuracy
2.1	G	A	G
2.2	A	< A	A
2.3	A	G	G

Table 1: Comparison Of Methods For Speed, Applicability And Accuracy. G Indicates Good, A Indicates Average And < A Indicates Below Average

4.Conclusion

This paper has compared three MRI signal intensity standardization methods in terms of speed, applicability and accuracy. Method A is fast and in general provide good results but it is vulnerable to distortions in the histograms due to the fact that it is piecewise linear and relies on a learned histogram shape. More sophisticated methods that make use of all image sequences or do pixel wise correction estimation are of course slower but lead to better results (Method C), whereas method B leads to worse results. All methods can be potentially applied to everybody area excepting method B which uses head specific tissue classes.

5.Reference

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