Volumetric texture analysis of DCE-MR images of the breast using gray-level co-occurrence matrix method

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Introduction

Texture analysis using 2D-image-based gray level co-occurrence matrix method [1] has been demonstrated to be useful in distinguishing between malignant and benign breast lesions in contrast-enhanced MR images [2]. 2D texture analysis does not take advantage of the 3D data in breast MR images and requires high signal-to-noise ratio, which may not be available in dynamic studies. We hypothesize that an overall assessment of texture on the accurately segmented 3D breast lesions would yield improved differentiation performance than 2D analysis. We extend the conventional 2D texture analysis technique to 3D in the framework of gray-level co-occurrence matrix method, and assess the performance of textural features in the task of distinguishing between malignant and benign breast lesions.

Materials and Methods

Our database consists of 77 malignant lesions and 44 benign lesions. Dynamic contrast-enhanced magnetic resonance (DCE-MR) images were obtained using a T1-weighted 3D spoiled gradient echo sequence (TR = 8.1 ms, TE = 4 ms, flip angle = 30^0). The patients were scanned in the prone position using a standard double breast coil on a 1.5 T whole-body MRI system. After the acquisition of the precontrast series, Gd-DTPA contrast agent was delivered intravenously by power injection with a dose of 0.2 mmol/kg and a flow rate of 2 ml/s. Five postcontrast series were taken with a time interval of 69 s. Each series contained 64 coronal slices with a matrix of 128×256 pixels and an in-plane resolution of 1.25 mm × 1.25 mm. Slice thickness ranged from 2.0 mm to 3.0 mm depending on breast size.

We extend the conventional concept of 2D-image-based gray level co-occurrence matrix (GLCM) to 3D image. The difference of spatial locations of two voxels is described by a displacement vector $\mathbf{d} = (d_x, d_y, d_z)$. For an image of G gray levels, the $G \times G$ gray level co-occurrence matrix P_d for a displacement vector $\mathbf{d}$ is defined as follows. The entry (i, j) of P_d is the number of occurrence of voxel pair of gray levels i and j whose spatial locations are a vector $\mathbf{d}$ apart. In 3D, there are 13 independent directions corresponding to 26 displacement vectors (Figure 1).

We initially segmented the 3D breast lesions in DCE-MRI using an automatic approach that we previously developed [3]. Bilinear interpolation was performed on the first postcontrast image data to make the voxels isotropic. The lesion data were then equal-probability quantized into 128 gray levels. For each lesion, 13 gray level co-occurrence matrices were calculated from the quantized postcontrast data and added together to get a non-directional GLCM. Then 11 features related to second-order statistics [1] were calculated from the GLCM. The performance of each feature in the task of distinguishing between malignant and benign lesions was assessed using receiver operating characteristic (ROC) analysis [4]. The area under ROC curve (A_z) was used as a performance index.

Results and Discussion

For the 11 texture features under investigation, 7 features yielded statistically significant higher A_z values when 3D analyses were used than when 2D analyses were used (Table 2). We failed to show significant differences between 3D and 2D for the other four feautres. In conclusion, 3D texture analysis based on accurately segmented 3D breast lesions improved diagnostic accuracy as compared to 2D texture analyses based on 2D ROIs.

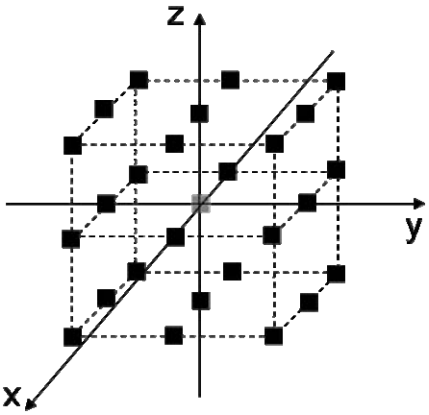

Figure 1. Illustration of 26 voxel pairs (gray and black) in 3D image space.

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References

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[3]. Chen W et al. *Acad. Radiol.* 2006; in press
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Table 1. Comparison of A_z values for 11 features in 3D and 2D texture analysis

(DE-difference entropy, DV-difference variance, IDM-inverse difference moment, SA-sum average, SE-sum entropy, SV-sum variance)

feature	contrast	correlation	DE	DV	Energy	Entropy	IDM	SA	SE	SV	variance
A_z (2D)	.51	.53	.52	.56	.59	.60	.55	.67	.62	.62	.77
A_z (3D)	.76	.69	.72	.76	.62	.65	.52	.62	.79	.86	.85
p	**0.006**	**.0005**	**.0001**	**$<10^{-4}$**	.66	.41	.76	.16	**.009**	**.0001**	**.02**