Malignant and Benign Breast Masses on 3D US Volumetric Images: Effect of Computer-aided Diagnosis on Radiologist Accuracy

Appendix E1

Feature Extraction

The feature vector for a given mass consisted of four width-to-height features, four posterior shadowing features, and 72 texture features.

The width-to-height features for a mass were the minimum, maximum, mean, and standard deviation of the ratio of the width to the height of the segmented mass for each section containing the mass. The width *(W)* and height *(H)* of the segmented mass in a section were defined as the widest and the tallest cross sections of the mass in that section, respectively (Fig 3).

The posterior shadowing features for a mass were the minimum, maximum, mean, and standard deviation of the feature extracted from each section containing the mass. In a given section, the posterior region of the mass was divided into n overlapping vertical strips (Fig 3). The width of each strip was equal to $W/4$, and the height of the strip was equal to H. The strips were defined only posterior to the central $3W/4$ portion of the mass so that bilateral shadows that are sometimes associated with fibroadenomas could be avoided. Let P denote the mean gray-scale value within the darkest posterior strip and M denote the mean gray-scale value within the segmented mass. The difference *(D)* between M and P defines how dark the US image is in the darkest posterior strip of the mass compared to the average within the mass. The posterior shadowing feature for the section was defined as the normalized difference D/M.

The texture features were extracted from disk-shaped regions posterior and anterior to the mass. These equal-size regions contain partly the interior portion of the mass and partly the mass margins. The total area of the anterior and posterior regions is equal to the area of the segmented mass. An example of the anterior disk-shaped region is shown in Figure 3. In each section containing the mass, spatial gray-level dependence (SGLD) matrices, $S(d, \theta)$ were extracted. The $(i,j)^{th}$ element of $S(d, \theta)$ is the relative frequency with which two pixels, one with gray level i and the other with gray level j, separated by a pixel-pair distance d in a direction occur in the image. In the present study, three pixel-pair distances, $d = 2$, 4, or 6 pixels, and two pixel-pair angles, 0° and 90°, were used. In each section, we therefore extracted six SGLD matrices from the anterior and

six SGLD matrices from the posterior disk-shaped regions. From each SGLD matrix, six texture features were extracted. These features were information measures of correlations 1 and 2, entropy, difference entropy, sum entropy, and energy. The mathematical definitions of these features can be found in the literature. The texture feature vector extracted from a section was therefore 72-dimensional. These vectors were averaged over all sections containing a mass to obtain the texture feature vector for the mass.