An algorithm for extracting the skin surface in MR breast images

M. A. Wirth[1], R. Wang[1], A. Stapinski[1]
[1]University of Guelph, Guelph, Ontario, Canada

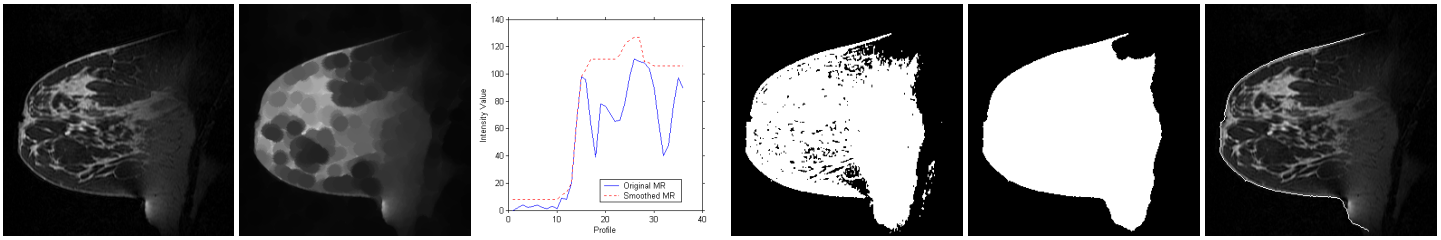
Synopsis
Segmentation of 2D MR breast images is usually composed of detecting (i) the breast/air boundary (skin edge) and (ii) the chest wall boundary. The individual 2D contours representing the skin edge can then be integrated to form a 3D representation of the skin surface. Extraction of the breast region through identification of the breast contour marks the outer margin of the breast, making it possible to exclude the non-breast region from the search for abnormalities. This paper outlines a simple algorithm to extract the skin surface from MR breast images.

Introduction
The 3D boundary surface of the breast is an intuitive and easily characterized feature that can be used to augment various analysis techniques. For instance it could be used to improve comparative analysis by confining the scope of a registration algorithm, or facilitate 3D visualization. The skin boundary surface can be used for image-to-physical registration. For instance in augmented reality surgery, a laser range scanner can be used to acquire depth data of the skin surface of the breast where the surgery is to be performed. An intra-operative open-MR scan outlining the anatomy of the breast (e.g. location of major blood vessels, localization of the tumor) is automatically registered to the patient skin surface depth data obtained by the 3D laser range scanner.

Method
The task of segmenting an MR image of the breast is less complex than that of segmenting the breast region of a mammogram due in part to the uniformity of the non-breast region of the image and the distinct boundary between the breast and non-breast regions. The background in MR images is air, which has little free protons and therefore produces a near-zero MR signal. Therefore the boundary of the breast with air is characterized by a sharp increase in the MR signal when approaching from the background region. This algorithm generates a series of two-dimensional contours in contiguous images slices that are coupled together to form a 3D surface [1]. The segmentation algorithm described here is based on morphological analysis and simple thresholding. Similar techniques have been used by Maintz et al. [2] to extract features from intermodal (MR, PET, SPECT) images of the brain using morphological operations.

Firstly a morphological grayscale closing operation is performed to prepare the image for thresholding, effectively applying a form of morphological smoothing on the MR images. Grayscale closing is a combination of grayscale dilation followed by erosion. Dilation has the net effect of choosing the highest intensity value in a given region, whereas erosion is the dual operation of choosing the lowest intensity value in a given region. This has the effect of attenuating the brighter areas of the breast image, and smoothing out any irregularities. Next a Minimum-Error thresholding technique [3] is applied to the processed image to calculate an appropriate threshold value to separate the breast region from the background. The next step is to label the connected components in the binary image and extract the largest connected region using 8-connectivity. There are typically many separated regions, mainly due to noise. It is consistent to assume that the breast region will produce the largest connected region, since this assumption will be violated only under extreme conditions. The extracted region may contain "islands" which are filled using morphological reconstruction [4]. The contour representing the surface of the breast is then extracted using contour tracing. The individual 2D contours are then used to generate a 3D surface which can be visualized using a technique such as iso-surface rendering.

Results and Discussion
We have developed a simple algorithm for extracting the skin surface in MR breast images. It can be used to partition the MR image into breast and non-breast regions, and as a possible feature for 3D registration. Figure 1 illustrates the algorithm applied to a sagittal MR breast image. The original image and its morphological greyscale closing are shown in Figure 1a and 1b respectively. To illustrate morphological smoothing, two intensity profiles have been mapped across the breast/air boundary in Figure 1a and 1b. The smoothed image is then thresholded (Figure 1d), labelled using a connected components algorithm and filtered to remove spurious regions, producing the final segmented image shown in Figure 1e. To visualize the effectiveness of the algorithm, the anterior breast contour has been superimposed on the original image(Figure 1f).



(a) *(b)* *(c)* *(d)* *(e)* *(f)*

Figure 1: Extraction of the breast contour from a sagittal MR image of the breast. (a) The original image; (b) Morphological grayscale closing; (c) Intensity profiles of (a) and (b); (d) Thresholded image; (e) Final partitioned breast region; and (f) Contour superimposed on (a)

References
1. Meyers, D., Skinner, S., Sloan, K., "Surfaces from contours", ACM Transactions on Graphics, 1992, Vol.11, pp.228-258
2. Maintz, J.B.A., van den Elsen, P.A. and Viergever, M.A., "Registration of 3D medical images using simple morphological tools," Information Processing in Medical Imaging, 1997, Vol. 1230, pp. 204-217.
3. Kittler, J., Illingworth, J., "Minimum error thresholding," Pattern Recognition, 1986, Vol.19, pp.41-47.
4. Soille, P. Morphological Image Analysis: Principles and Applications, Springer-Verlag, 1999, pp. 173-174.