IMAGE FUSION IN 3D ULTRASOUND SCAN OF RESIDUAL LIMBS

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Abstract: An ultrasound system for imaging residual limbs has been developed that employs a fast vertical scan mode and a compound horizontal scan mode. In this paper, a method for fusing the data acquired from these two scan modes into a 3D volumetric image is described. Result from scanning a residual limb is presented.

Keywords: Image fusion, Ultrasound imaging

Introduction

An ultrasound scanning system for imaging residual limbs has recently been developed [1]. The system employed two scan modes: a vertical scan mode to quickly capture the skin surface with a high vertical resolution and a compound horizontal scan mode to obtain high quality cross sectional images, showing the internal structure of the limb. Because the data obtained in the two scan modes have different characteristics, we have developed a special algorithm that fully utilizes the advantages of each scan mode and optimizes the resolution and quality of the final 3D image.

Method

The skin surface is extracted from the data obtained from the vertical scan that takes approximate 1 minute to perform. As a result, the data is largely free of motion artifacts. In addition, the vertical images provide a high resolution in the longitudinal direction. Since the horizontal scan takes more than 10 minutes, certain limb movement during the scan is inevitable. A motion detection and compensation algorithm is first applied to each of the 36 images obtained in every cross section level before compounding. In addition, an accumulate table is generated which stores the number of times that each pixel in the compound image has been updated during compounding. The information of this table will be used later in 3D image fusion.

To reconstruct the 3D volumetric image, the vertically scanned images and compound images must first be aligned properly. To perform the alignment, we first extract the skin boundary from each compound image, and then find the corresponding skin contour from the vertically scanned images. Next the center of gravity of each boundary is calculated. The difference between the two centers defines a 2D vector that is the required shift for aligning the compound image with the vertically scanned images.

To fuse these two aligned sets of images into a 3D volumetric image, we first map a voxel in the 3D coordinates on to 2D coordinates of the compound image field as well as the vertically scanned image field. The intensity of a 3D voxel is then calculated from the intensities of the eight closest neighboring pixels in each of the two image fields using linear interpolation:

\[
I(v) = \frac{\sum_{i=1}^{n} I_{hi}(v) E_{i}(v) + \sum_{j=1}^{m} I_{hj}(v) E_{j}(v)}{\sum_{i=1}^{n} E_{i}(v) + \sum_{j=1}^{m} E_{j}(v)}
\]

where \(I(v)\) represents the intensity of voxel \(v\), \(I_{hi}\) and \(I_{hj}\) represent the intensity of pixel in the compound image field and vertically scanned image field, respectively. \(E_{i}(v)\) and \(E_{j}(v)\) represent the inverse distance between voxel \(v\) and the corresponding pixels of the two image fields. \(N(v)\) is the weight defined according to the accumlate table generated during image compounding. The accumulate table used here is to ensure that the interpolated voxel intensity is proportional to the energy of original ultrasound image data from both fields.

Result

The fusion result of a residual limb is shown in figure 1. The spatial resolution of the original compound image field is approximately 0.3516×0.3516 mm², and the spatial resolution of the vertically scanned image field is 0.3349×0.3478 mm². After fusion, the voxel resolution of the 3D volumetric image is 1×1×1 mm³.

Discussion

The main advantage of this fusion method is to utilize high resolution of the vertically scanned images along the vertical cutting slices and better quality and details of the compound images along the horizontal cutting slices. Even with a much reduced voxel resolution, the fused 3D volumetric image still shows high image quality in bony and tissue structures and smooth skin surface contour. A visualization tool to explore the fused 3D volumetric data for prosthetic socket design is reported separately.

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Reference