Enhancement of Instrument Appearance in Ultrasound Images by Distribution and Spatial Analysis

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Introduction and Method

New real-time 3D ultrasound (US) promises to enable new intracardiac beating heart and fetal procedures [1]. However, the distorted appearance of surgical instruments is a major challenge. While echographic images are fast and cheap for use in the operating room, they are also noisy and hard to interpret. Tissue texture analysis has been used previously to segment cardiac images [4]. Tissue and instruments have similar grey levels in US images, which makes their correct delineation difficult. Furthermore, the interference between instruments and tissue is fuzzy and confusing to the surgeon.

Our work estimates from expert-segmented images the statistical distributions of blood, parenchyma and instrument in intracardiac procedures. First, we build averaged probability distribution functions for the three mentioned classes. The voxel intensity used to determine its class uses information from the neighbouring voxels through a smoothing kernel of determined size and standard deviation. The labelling of voxels is done through an iterative expectation-maximisation algorithm [2]. More neighbouring information is used to give a spatial measure based on the shape of instruments to correct for misclassified voxels. We employ a small central kernel around the voxel (3x3x3 voxels), a larger neighbouring kernel (7x7x7 outside the central one) to estimate the neighbourhood intensity and an even larger background kernel (21x21x21) to estimate the intensity of voxels further away from the centre and outside the neighbouring kernel. The relations between the three kernels aim to correct for voxels falsely labelled as tissue inside the instrument and vice-versa.

Results and Conclusion

We used both in-vitro data, from a tank trial with an acetal rod approaching a tissue sample, and in-vivo data, from a surgical operation performed with a wooden instrument in a porcine heart (no by-pass was performed). The training sets and test data are acquired under similar imaging conditions and using the same instrument material. All data was acquired with a Philips Live 3D Echo Scanner. Classification results are shown in Figure 1 (in-vitro data) and Figure 2 (in-vivo data). Some of the major classification errors appear at the tissue edges and parenchyma in the proximity of the US probe, as the spatial measures are not complex enough for the in-vivo data.

Figure 1: Tank data: (a) a slice of a 3D US image of an acetal rod approaching a tissue sample in a water tank; (b) detection results without spatial information, where the instrument is shown in white and the tissue in grey; (c) detection results employing spatial information.

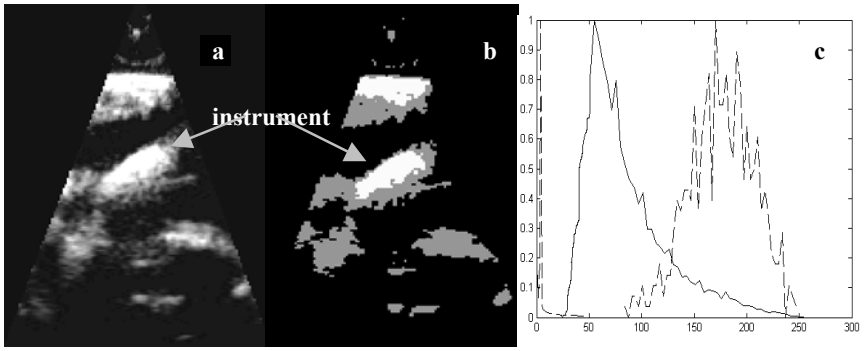

Figure 2: In vivo data: (a) a slice of a 3D US image of a porcine heart with a wooden rod inside (in contact with the tissue) acquired in clinical conditions; (b) detection results, where the instrument appears white and tissue grey; (c) the normalised histograms of (from left to right): blood, parenchyma and instrument.

For future work, more spatial and statistical information using the instrument shape and principal factor analysis [3] will be implemented. Image normalisation will be used to make the method more robust and neighbourhood analysis and connectivity to correct segmentation errors. Our preliminary results are 3D; we will also employ temporal information of instrument movement from 4D US clinical images.

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