Shape-Based Interpolation of MRI Volumes in TRUS/Fusion Based Biopsy

X. chen[1], R. Narayanan[2], J. Kurhanewicz[3], K. shinohara[4], D. Crawford[5], A. Simoneau[6], and J. S. Suri[2]

[1]Eigen Inc., Grassvalley, CA, United States, [2]Eigen Inc., [3]University of California, San Francisco, United States, [4]University of California, San Francisco, [5]University of Colorado, Denver, Denver, [6]University of California, Irvine

Abstract

The purpose of this project is to develop a fast shape-based inter-slice interpolation scheme to transform anisotropic MR images to isotropic images while preventing blur and artifacts. This project is motivated by the need to reduce the partial volume effect of large slice thickness of MRI so that the subsequent segmentation, reconstruction and registration can be done with higher accuracy during TRUS/MRI fusion guided biopsy in ei-Nav/Artermis™ .

Introduction

MRI has been widely used for monitoring and guidance in many clinical procedures such as the diagnosis and treatment of prostate cancers. However, the accuracy of real-time MRI processing such as segmentation, reconstruction and registration has been reduced by the partial volume effect because of the typical large slice thickness of MRI slices [1]. The conventional intensity-based interpolations undergo image degradations such as blur and additive noise [2], and the diffusion-based methods are not practical for use due to less testing and experience, and high time complexity [3]. To overcome this obstacle, a fast shaped-based interpolation (SBI) scheme was developed in this paper to increase the inter-slice resolution while maintaining a low level of blur, artifact and noise. The GPU-based multithread (NVIDIA CUDA) programming dramatically reduces the order of elapsed time from hours to seconds. This method was applied for the transrectal ultrasound and magnetic resonance imaging (TRUS/MRI) fusion guided biopsy in Artemis ™ [4].

Method

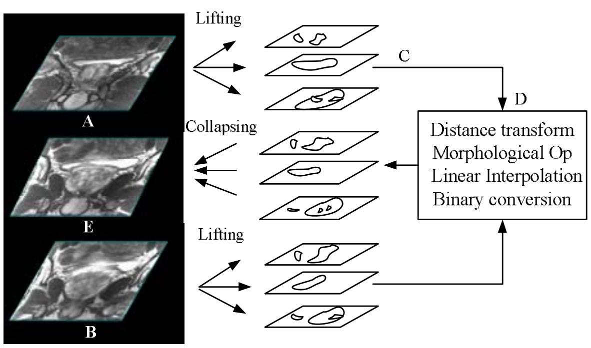

Figure 1: SBI workflow. (A,B) original MRI slice of prostate; (C) level lines; (D) processing on distance maps; (E). reconstructed intermediate grey-level images.

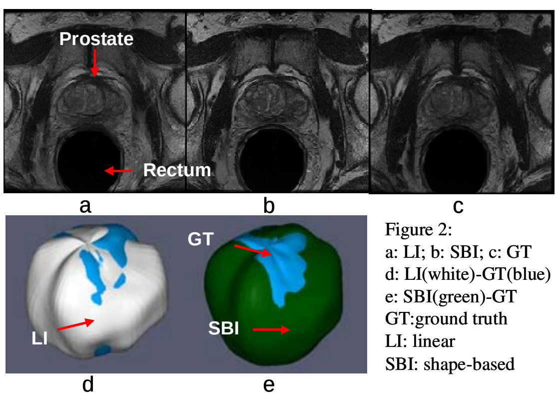

Figure 2:
a: LI; b: SBI; c: GT
d: LI(white)-GT(blue)
e: SBI(green)-GT
GT:ground truth
LI: linear
SBI: shape-based

A fast shape-based interpolation method has been developed to obtain isotropic images by interpolating the inter-slice MR T2-weighted prostate images acquired with Turbo-spin-echo (TSE) sequence. Distance transform was performed on the stack of binary images which were lifted from a single grey image based on all level sets (Figure 1). Morphological operation was conducted on the distance maps to reduce the noise level. The intermediate distance maps of all level sets were obtained by interpolating the signed distance maps of two adjacent anisotropic images (Figure1, A and B). The binary conversion was performed based on the zero level sets of these intermediate distance maps. In the end, the intermediate grey-level images were constructed by collapsing all the binary images based on all the levels of intensities. The degree of blur induced by interpolation is much lower in this shape-based method because no grey levels were newly generated in the constructed images so that the high frequency information could be conserved. To evaluate the utility of this approach, this shape-based method was applied on representative clinical cases of prostate (n=200) and compared with linear interpolation results. Five metrics used for performance evaluation include signal-to-noise ratio, anti-blur, surface shape matching, volume-based evaluation and time-complexity. The matching degree of the shape of the prostate segmented using discrete-dynamic-contour (DDC) method between the shape-based interpolation and ground truth is evaluated using the mean squared differences between the points on the prostate contours. A parametric statistical test was applied to show that signal-to-noise ratio in shape-based interpolation images are improved compared with the linear interpolation and raw image. Multithread parallel operation of distance transform was achieved by using compute unified device architecture (NVIDIA, Santa Clara, California) running on a GeForce 8800 GTS graphic processing unit.

Results

Figure 2 showed the interpolated images and 3D surface reconstructed based on the DDC segmentation on these images. The statistical analysis showed that the SNR of shaped-based image is about 10% higher than linear interpolation with p value = 0.65 according to a two-tailed t-test. The volume measure metrics indicated that the mean of the volume difference between the shape-based-interpolated estimates and the ground truth across all patients was reduced by 40% compared with that between without-interpolation images and ground truth images. The volume estimate of prostate in shape-based image is of 10% less variance than linear interpolation. The surface shape metric demonstrated that the SBI image is highly corresponding to the surface of the ground truth (p value = 0.56). The maximal gradient in SBI image is 10% higher than linear interpolation (p value = 0.86), demonstrating less blur in the former. The system works in near real time (1 sec per image pair).

Conclusions

This shape-based interpolation method for inter-slice interpolation of MRI prostate images to significantly improve the accuracy of the segmentation of prostate based on MRI images is a useful tool for improving the diagnosis and treatment of prostate.

References:

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