A NEW VOXEL GRAYSCALE BASED 3D IMAGE REGISTRATION VALIDATION METHOD

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INTRODUCTION

Registration, or accurately aligning multiple images of the same subject or specimen, is vital to three-dimensional analysis of bone microstructure. Validation is required during development of new registration techniques and for evaluating the performance of existing techniques. Physical landmark methods are usually employed to validate other registration techniques because they have a reputation for accuracy [1]. However, it is difficult to implement a landmark validation method for micro level registrations or to evaluate the registrations with a geometry variance problem caused by bone growth or adaptation.

We developed a new validation technique that can be used without limitations for mono-modality registration validation.

METHODS

This voxel grayscale based technique takes advantage of the similarity of the net bone formation percentage (%NBF) in the adjacent regions within a bone. A small region, A_1 (Figure 1), from the reference image is selected and the bone volume fraction (BV) calculated. A region A_2, which has the same size and same position as A_1, is selected from the registered floating image and the bone volume fraction calculated. The %NBF or volume fraction ratio R_A is given by

$$\%\,NBF = R_A = \frac{BV_{A2}/TV_A}{BV_{A1}/TV_A} = \frac{BV_{A2}}{BV_{A1}} \quad (1)$$

A region B_1 from the reference image, in close proximity to A_1, is selected together with B_2 in the registered floating image and the %NBF calculated by

$$\%\,NBF = R_B = \frac{BV_{B2}/TV_B}{BV_{B1}/TV_B} = \frac{BV_{B2}}{BV_{B1}} \quad (2)$$

For well registered images with geometry variance, the %NBF should be approximately equal for equation (1) and (2). That is $R_A/R_B \approx 1$ which is defined as the ratio of percentage (RP). A good image registration will have a RP mean of approximately 1.0 with a small standard deviation.

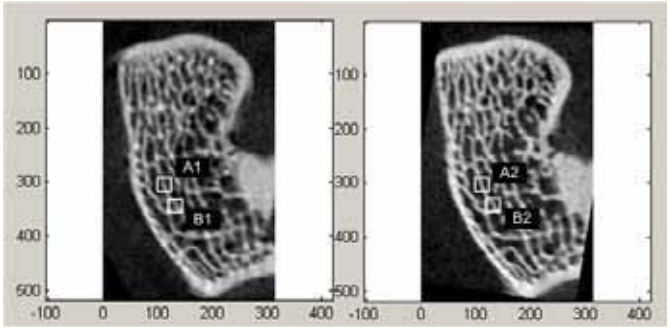

Figure 1: Slices chosen from reference image (left) and corresponding registered image (right).

This method is able to distinguish the registered images from unregistered images for nearly all the selected region sizes (SRS), as shown in Figure 2, where three registered and unregistered image pairs were tested. The SRS was set to 25 voxels in this study. The distance between A_1 and B_1 was set to 10 voxels which was shown to have no significant effect on the validation results. For each validation, twenty selected region groups were used to stabilize RP and the STDV.

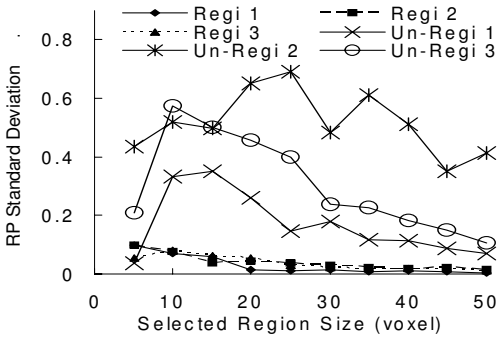

Figure 2: Validations for registered and unregistered images.

RESULTS AND DISCUSSION

Seven rabbit distal femurs were scanned, in vivo, at 28μm nominal resolution in a custom open frame micro-CT system (ACTIS 150/225 FFi-HR CT, BIR Inc., Chicago, IL) with 14 or 28 days time-intervals. The images were registered by a custom designed software package using the maximization of mutual information method which is considered to be accurate [1] and then validated. The RP means were all nearly 1.0 and the standard deviations were approximately 0.1 as shown in Figure 3.

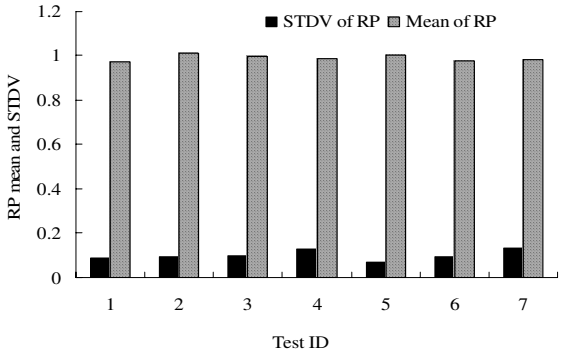

Figure 3: The RP mean and standard deviation for seven registrations.

This new grayscale based method can be used case by case to validate the registrations where existing techniques do not apply. The minimum registration error it can detect has been shown to be one voxel.

REFERENCE

1. West et al. Journal of Computer Assisted Tomography. 21 (4): 554-566.