Elastic Registration based Interpolation of MRI Images in 3D

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Introduction:

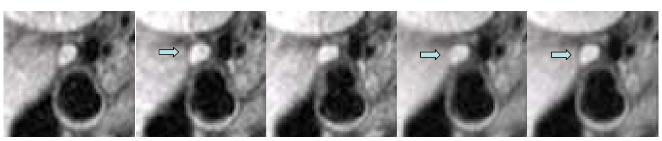
In MRI, resolution in the through-plane direction is often substantially worse than in-plane resolution, particularly for two-dimensional acquisition protocols. When possible, this limitation is addressed by aligning the images such that the rate of change of the object in the out of plane direction is minimized. For example, in the protocol for in vivo carotid artery MRI imaging [1] the images are prescribed perpendicular to the long axis of the artery, permitting the spacing between adjacent images to be 2.0mm whereas the in-plane resolution is 0.5mm. Such alignment suggests that the image data can be interpolated in the through-plane direction to reconstruct intermediate image planes, taking advantage of the slow rate of change in the longitudinal direction. However, slight misalignments of the anatomic structure or variability in its orientation can cause simple interpolation efforts to fail. Large differences may even cause discontinuity of the anatomic structures. Here we propose an interpolation method to handle the difficulties above. Using non-rigid registration, the direction of minimal change is determined by the best matched corresponding voxels in adjacent images and interpolation is carried out in that direction.

Methods:

Given two adjacent MR images, we want to interpolate intermediate images between them. First, an elastic model [2] based non-rigid registration is applied using the second image as a reference. In the result, the shift vector from each pixel in the first image to the best match position in the second one is obtained. Where intermediate layers intersect these shift vectors the intensity is bilinearly interpolated from the best matched pixels. Then, from these estimated sampling points, the intensities at integer grid positions are computed utilizing a thin-plate-spline [3] interpolation method.

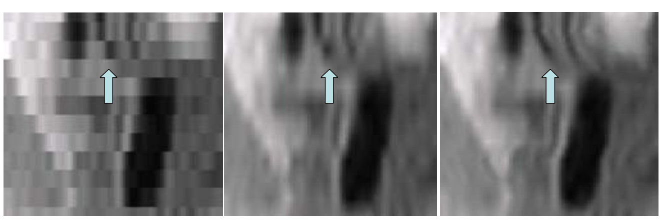
Results:

In the example in fig. 1, comparing to the direct bilinearly interpolated (d-interpolation) image in (d), the registration based interpolated (r-interpolation) image in (e) preserves a sharper boundary which reduces the partial volume effect. In composing an oblique image from a stack of axial images as shown in fig. 2, r-interpolation maintains the continuity of the small arteries better than d-interpolation. The difference is augmented at areas of stenosis. Statistical results of the accuracy of the interpolated image are shown in table 1. Both d-interpolated images and r-interpolated images are compared to actual MR images obtained at the intermediate location. On average, the d-interpolated image has an error of 44.2 and the r-interpolation method has an error of 41.8. Considering that the scanned images exhibit a noise standard deviation of 39.2, the percentage of large errors, that is higher than 2 times noise level, d-interpolation produced 7.0% and r-interpolation 5.6%.



(a) (b) (c) (d) (e)

Fig 1. Real and interpolated images (a-c) 3 adjacent MR images (d) d-interpolated image from a and c (e) r-interpolated image from a and c



(a) (b) (c)

Fig 2. Composed oblique image from axial MRI images (a) from raw data (b) from d-interpolation (c) from r-interpolation

Table 1. Statistical results of different interpolations

SNR	D-Int. err	R-Int. err	D-Int. big err	R-Int big err
496.5/39.2	44.2	41.8	7.0%	5.6%

Conclusion:

We proposed an elastic registration based interpolation method which interpolates intensity along the direction between best matched pixels in the adjacent scans. Adaptive to anatomic structures, this technique reduces partial volume effect and keeps structure continuity. Both the statistical result and visual observation show that the proposed method is superior to the traditional bilinearly interpolation method. It also reveals the possibility of analyzing 2D MRI images in 3D.

References

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3. Bookstein F L et.al. *IEEE TPAMI*, 1989; 11(6):567-585.