Registration of Supine and Prone CT Colonography Data using Dynamic Time Warping: Method and Evaluation

PURPOSE: To develop and experimentally validate a method to anatomically register complementary supine and prone CT colonography (CTC) datasets, by estimating a warping function between the medial axes of the supine and the prone data, based on minimizing a cost function.

METHOD/MATERIALS:

Let $f_j(t), t \in [0, M]$ and $g_j(t), t \in [0, N]$ with $j \in \{x, y, z\}$ represent the medial axes of colon acquired in supine and prone positions respectively in terms of their 3D coordinates parametrized by *t*, the path length along the medial axis. Our goal is to find a warping function $w(t)$ such that $f_j(w(t)), t \in [0, M]$ and $g_j(t), t \in [0, N]$ correspond to identical anatomical points. The medial axes are acquired by colon segmentation and automatic determination of a central colonic path extending from the rectum to the cecum and were sampled at 1mm intervals. The cost function we used is a weighted sum of squared distances between $f_j(w(t)), t \in [0, M]$ and $g_j(t), t \in [0, N]$ for $j \in \{x, y, z\}$. A weighted sum is used to reflect the relative importance of coronal, sagittal and axial dimensions. The minimization is performed in the discrete domain by a nonlinear match of the points sampled along the two paths and is solved by dynamic programming using the Dynamic Time Warping algorithm [Rabiner L. et al., Fundamentals of Speech Recognition, Prentice Hall, New Jersey]. One radiologist determined 5 unique reference points (RP) in each of 24 patients by viewing supine and prone data simultaneously. The method is evaluated by measuring the distance between those RPs along the medial axes (DoP). RPs included polyps, diverticulae, unique folds, or the ileocecal valve.

RESULTS: The registration decreased the mean±s.d. DoP between RP pairs on prone and supine paths from 47.08±48.2 mm to 9.11±11.04 mm (-80.6%). The maximum (minimum) DoP between RP pairs was decreased from, 226.0mm (1.0mm) to 85.0mm (0.0mm) after registration. The mean DOP of 13 among 120 RP pairs increased from 9.29±8.72 mm to 18.57±20.30 mm Linear regression analysis of pre- and post-registration DoPs showed that the registration is independent of initial mismatch.

CONCLUSIONS: Initial results suggest that our algorithm is capable of registering supine and prone CTC data anatomically within a mean range of ±9.11mm, which corresponds to 0.57% error with respect to the average colon length. This corresponds to a 28% improvement on registration compared to a previously proposed method [Li et al., Med. Phys. 31(10), pp.2912-2923, 2004] run on the same dataset.