AbstractID: 13333 Title: PCA-based lung motion model

Purpose: To theoretically study the effectiveness of principal component analysis (PCA) modeling of lung motion, and to investigate its applicability for clinical data.

Method and Materials: We first derived an important property which is concerned with the implicit regularization imposed by the PCA lung motion model, i.e., for any two voxels with similar motion, their motion represented by PCA will also be similar. We then introduced two respiratory phantoms based on simple and yet realistic assumptions, where each voxel in the lung moves with cosine motion or an even power of cosine motion, both with arbitrary amplitudes and phases. We then applied the PCA model on two patient 4DCT data sets to test the modeling accuracy.

Results: We proved that for respiratory phantoms with cosine and an even power ($2n$) of cosine motion, 2 and $2n$ PCA coefficients and eigenvectors will completely represent the lung motion, respectively. Moreover, for the respiratory phantom with cosine motion, we derived the equivalence conditions for the PCA motion model and the physiological 5D lung motion model (Low 2005). When tested on clinical data, the average 3D RMS model error was found to be below 1 mm using only 2 PCA coefficients.

Conclusion: We have presented the theoretical analysis and clinical validation of a lung motion model based on PCA. Potential clinical applications include removing motion artifacts in 4DCT, lung motion tracking from implanted markers, surface imaging, or x-ray projection images.