Comments on 'Ventilation from four-dimensional computed tomography: density versus Jacobian methods'

2011 Phys. Med. Biol. 56 3445

(http://iopscience.iop.org/0031-9155/56/11/N03)

Phys. Med. Biol. **56** (2011) 3445–3446 doi:10.1088/0031-9155/56/11/N03

COMMENTS AND REPLIES

Comments on 'Ventilation from four-dimensional computed tomography: density versus Jacobian methods'

Geoffrey Zhang[1], Tzung-Chi Huang[2], Thomas Dilling[1], Craig Stevens[1] and Kenneth Forster[1]

[1] Radiation Oncology, Moffitt Cancer Center, Tampa, FL, USA
[2] Department of Medical Radiological Technology, China Medical University, Taiwan

E-mail: geoffrey.zhang@moffitt.org

Received 10 December 2010, in final form 24 January 2011
Published 16 May 2011
Online at stacks.iop.org/PMB/56/3445

We read with interest the article by Castillo *et al* (2010) on comparison of ventilation calculations from 4D-CT images between density and Jacobian methods. In this work, the authors performed ventilation calculations from 4D-CT images using three published methods and compared the results with ^{99m}Tc-labeled aerosol single photon emission computed tomography (SPECT) for seven patients who had 4D-CT and SPECT images taken on the same day. The SPECT images were considered the gold standard for comparison. The three methods included in their comparison are (1) density-based specific ventilation (Guerrero *et al* 2006), (2) Jacobian-based specific ventilation (Reinhardt *et al* 2008), referred to as analytic implementation of the Jacobian method in Castillo *et al* and (3) geometry-based specific ventilation (Zhang *et al* 2009), referred to as Jacobian-based specific ventilation: geometric implementation in Castillo *et al*. The authors concluded that all the methods correlated well with global measurements of the resting tidal volume. The Dice similarity test performed in their study showed similar coefficients between the SPECT percentile ventilation and all three methods, with slightly higher correlation between SPECT and the density-based method.

We appreciate the inclusion of our method in their study and their demonstration of the validity of our approach. However, we also noted that the authors used our method in the study but without referencing to our work, and the paper is vague regarding the origin of this method. This may be an oversight as our paper was published in the proceedings of World Congress on Medical Physics and Biomedical Engineering and may not be readily accessible.

We also believe that the authors were slightly in error, as the original Jacobian-based method, called 'analytic Jacobian' in this paper, uses the Jacobian of the transformation that maps image I_0 to image I_1 to estimate the local volume change (Reinhardt *et al* 2008). First-order partial derivatives of the vector displacement function are the elements in the Jacobian

matrix. As our method does not use the derivative of the transformation matrix, our method is not a Jacobian method. Our method is a brute force geometric calculation method. The volume calculation is basically the sum of six tetrahedrons which are originally defined by eight voxel vertex positions in expiration and then deformed in inspiration. For each tetrahedron, volume $V = (\boldsymbol{b} - \boldsymbol{a}) \cdot [(\boldsymbol{c} - \boldsymbol{a}) \times (\boldsymbol{d} - \boldsymbol{a})]/6$, where $\boldsymbol{a}, \boldsymbol{b}, \boldsymbol{c}, \boldsymbol{d}$ are the vertices as vectors, which is simple and easy to derive. A Jacobian is a mathematically well-defined term, and does not need the adjective such as analytic or geometric. There is only one Jacobian and clearly having two types of Jacobian methods does not make sense. The authors of the paper used a matrix derivation and the logic: if A $\approx$ B and B = C, then A = C, to show that our method is a Jacobian method. We believe that this derivation is farfetched and irrelevant to the topic of the paper. It may confuse readers. We agree that the calculations by the Jacobian method and our geometric method are close to each other. But it is common sense that different methods may arrive at the same result.

References

Castillo R, Castillo E, Martinez J and Guerrero T 2010 Ventilation from four-dimensional computed tomography: density versus Jacobian methods *Phys. Med. Biol.* **55** 4661–85

Guerrero T, Sanders K, Castillo E, Zhang Y, Bidaut L, Pan T and Komaki R 2006 Dynamic ventilation imaging from four-dimensional computed tomography *Phys. Med. Biol.* **51** 777–91

Reinhardt J M, Ding K, Cao K, Christensen G E, Hoffman E A and Bodas S V 2008 Registration-based estimates of local lung tissue expansion compared to xenon CT measures of specific ventilation *Med. Image Anal.* **12** 752–63

Zhang G G, Huang T C, Dilling T, Stevens C and Forster K M 2009 Derivation of high-resolution pulmonary ventilation using local volume change in four-dimensional CT data *World Congress on Medical Physics and Biomedical Engineering (IFMBE Proceedings* vol 25/IV*)* ed O Dössel and W C Schlegel (Munich: Springer) pp 1834–7