Feasibility of data redundancy for on-line geometric calibration without dedicated phantom on the Varian OBI CBCT systems: A simulation study

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Purpose: Most common method of geometric calibration is based on the analysis of the projection data of dedicated phantoms, composed of a certain number of fiducial markers. From the relationship between 3D points of fiducials and their 2D projected locations at various gantry position, various geometric parameters of the system can be identified with good accuracy. However, extra-scan of a calibration phantom is inevitable, moreover, precise 3D and 2D information of phantom shape and position is necessary for accurate results. Therefore, in this work, we proposed a new object function based on data redundancy for geometric calibration, which uses projection data of any arbitrary patient already scanned.

Materials and Methods: Among various types of data redundancy condition, we exploited fan-beam based data redundancy but also can be extended to cone-beam projection data of either full-fan or half-fan geometry. As a pair of redundant data point traversing the object along the same line of projection should be same in the case of no geometric misalignment, the squared difference of them is believed to be available as a cost function to detect current geometric parameters. To validate the proposed function, we performed the simulation study using the XCAT numerical phantom with a system geometry of Varian OBI. We acquired projection data by changing 8 types of geometric parameters at 1 mm or 1 degree intervals, and check the sensitivity of the cost function with respect to the parameters.

Results: In both full-fan and half-fan geometry, the proposed cost function is capable to detect geometric misalignments. In details, the transversal shift and the rotations of the detector were easily perceived, however the longitudinal shift and the error of SDD (distance of the source point to the detector) were detected with relatively low sensitivity.

Conclusions: In this work, we proposed a new cost function based on data redundancy which can be exploited for geometric calibration of CBCT. The results of a simulation study showed that every geometric misalignment can be detected, but there was a difference in the sensitivity of each parameter. We envision that the calibration method of geometric misalignments can be established with the proposed method, and the ongoing study includes such implementation of it. Future work will be also towards further validation with patients' data.

Keywords: Geometric calibration, Data redundancy, Cone-beam CT