Reviewer's report

Title: Multimodal image registration of the scoliotic torso for surgical planning

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Reviewer: FRANJO PERNUS

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The authors present a framework for registering magnetic resonance (MR) images of the torso and the surface topography (TP) of the torso to the reconstruction of the spine, obtained from biplanar X-ray imaging. The idea is to register the MR image to the X-ray reconstruction, and the TP image to X-ray reconstruction to obtain a three-dimensional (3D) model of the torso. Registration is needed because MR images are acquired in patient supine position, while TP and X-ray images are acquired in patient standing position. The possible application of the presented methodology is interesting, however, some parts of the manuscript need additional attention in order to improve its clarity.

Major Compulsory Revisions

1) The framework was evaluated on three scoliotic patients. The database is not big enough to guarantee enough statistical power for the study. Moreover, no information on patient sex, age degree of scoliosis, etc. is provided.

2) For acquisition of TP and X-ray images, different markers were placed on the torso of the patient. However, the authors state that they were placed at the same location. How exactly was this achieved unless the same markers were used?

3) A major concern is that the MR images used for registration were axially acquired cross-sections. However, sagittal cross-sections with higher resolution were also acquired, from which the vertebrae were manually segmented and then used to align the bone structures in axial cross-sections to the reconstructed X-ray model. This is a big drawback of the proposed method, as by this approach the location of each axial cross-section along the z-axis in relation to the reconstructed X-ray model is known. Moreover, the segmentation procedure was not described and the accuracy of such segmentation was not reported.

4) To register the soft tissues, corresponding points are obtained from the current MR axial cross-section and from the TP data by simply placing points on edges 30 degrees apart. How do you ensure correspondence in this case? The authors “deem these correspondences to be sufficiently accurate”, but what exactly is the accuracy (and precision) of such correspondence?

5) Once the corresponding points on the edges are defined, it is not clear whether these points are the control points that drive the thin-plate spline transformation in the registration procedure.
6) The final registration is performed to align the MRI soft tissue with the reconstructed X-ray model. The geometric transformation is weighted with the distance of the observed point to the edge of the torso, which can be easily obtained from the axial cross-section, and with the distance of the observed point to the vertebra, probably obtained from the manually segmented sagittal cross-sections. Here, the manually segmented data again play a significant role in the methodology.

7) Throughout the methodology, it is not completely clear what do the authors mean by composition of transformations, especially in Eq. 2 where they compose a global transformation from local transformation of each vertebrae. In the end, however, they register each MR axial cross-section, which is already aligned in z-direction, to the reconstructed X-ray model and TP data.

8) The evaluation of the registration results is quite poor. Besides Dice coefficient and image of the determinant of the Jacobian deformation field, several other measures are used to evaluate the registration performance. The authors should provide a more elaborated evaluation of the results.

9) To calculate the Dice score, the authors use the mask of the torso in the MR cross-section and a planar cut of the TP data at the same position. Which position of the TP is assumed here, meaning do the authors assume that the TP data is perfectly registered so that the planar cut refers to the same anatomy, or is there a bias in such evaluation?

Minor Essential Revisions

10) The thin-plate spline transformation in Eq. 1 was implemented using $U(r) = |r^3|$. Why was among all possible radial function this one chosen? How exactly were the coefficients for the rigid part, and how exactly were the weight for the non-rigid part estimated?

11) The fact that registration was performed independently for each MR axial cross-section is methodologically not very appropriate despite the cross-sections are quite apart (12 mm). For example, the cross-sections could be connected into a chain.

12) In the paragraph after Eq. 3 there is an unfinished sentence on the approximation of the “preliminary thin-plate spline transformation” for soft tissue to MR image.

13) The manuscript has to be proof read for several typos and grammatical mistakes.

Discretionary Revisions

14) Figures 6 and 7 could be augmented by the actual MR axial cross-sections that exists behind the shown image of the determinant of the Jacobian.
Level of interest: An article whose findings are important to those with closely related research interests

Quality of written English: Needs some language corrections before being published

Statistical review: No, the manuscript does not need to be seen by a statistician.

Declaration of competing interests:

I declare that I have no competing interests.