FAST STEREO-RADIOGRAPHIC 3D-RECONSTRUCTION OF THE SPINE USING A GEOMETRIC AND STATISTIC BASED MODEL

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INTRODUCTION

Accurate 3D-reconstructions of the spine may be obtained from stereo-radiography (Mitulescu, 2001). However identification of 25 to 28 landmarks per vertebra are necessary to reconstruct a whole scoliotic spine, which makes the process long (more than 2 hours) and tedious. The purpose of this work is to propose an original method for an accurate and fast 3D-reconstruction.

METHODS

The prerequisites of the method are the calibration of the radiological environment and the digitization of the corners of the projected vertebral plates of the vertebra on both views (Frontal and Sagittal X-rays). This step can be semi-automated (Deschênes, 2003) or manually performed.

Fast 3D-reconstruction of each vertebra is obtained using the following process:

Once the four projected corners of the vertebral plates are localized in both X-rays for each vertebra, each vertebral body is positioned in 3D-space using the following technique. Two pyramids are defined that enclose vertebral walls and end plates. Their bases are defined by the projected corners of the vertebral body in each view and the top corresponds to the X-Ray source location. A hexahedron per vertebra is then built as the intersection and the combination of the two pyramids. The 3D-orientations of the top and bottom planes of the hexahedron strictly define the 3D-orientation of the endplates of the vertebral body. Moreover, each vertebral body is exactly enclosed within its associated hexahedron.

A local vertebral referential is defined as follow. Origin is the barycentre of each hexahedron. Sagittal and lateral angles of vertebrae are computed from the projections of the hexahedron’s faces associated to each vertebra (Skalli, 1995). The third angle, axial rotation, is statistically estimated from a database of 96 in vivo spines reconstructed from stereo-radiographies (Dumas, 2002 and unpublished data). 8 descriptors of the vertebral body dimensions are calculated considering the local referential and the hexahedron associated to the vertebra. Then, these 8 descriptors were used to estimate specific 3D coordinates describing the whole vertebral shape, thanks to a database of 1628 dry vertebrae (0.2 mm precision - Laporte, 2000; Parent, 2002; Semaan, 2001), which includes direct measurements of about 180 3D points per vertebra. Those points are then replaced within the global frame, and a 2000 point model of the vertebra to be reconstructed is then kriged with the above mentioned control points. By applying this algorithm at each spinal level, the spine is reconstructed.

Evaluation:
Evaluation of the method was performed by comparing this automatic reconstruction (AR) versus the manual reconstruction (MR) and CT-scan reconstructions (CTR). Comparison focused on orientation of the vertebra (for AR and MR methods), and point to surface distance of the 2000 point vertebral models obtained by all methods. 61 vertebrae (32 for AR vs. MR comparisons and 29 for AR vs. CTR), from T2 to L5 were considered on 10 scoliotic patients.

RESULTS AND DISCUSSION

The algorithm was implemented in a specific C++ application, and 3D reconstructions were obtained within few seconds with a 1GHz processor (Figure 1).

Figure 1: Landmarks and the fast 3D-reconstruction.

Comparison yielded the following results: For orientations, mean differences (Standard Deviation) were -0.7° (2.9°), 1.4° (4.2°) and -0.1° (6.2°) for lateral, sagittal and axial angulations respectively. Shape RMS differences on 2000 points per vertebra was 1.2 mm (AR vs. MR) and 2.1 mm (AR vs. CTR). AR accuracy was similar to MR method (Mitulescu 2002). Therefore the a priori knowledge is sufficient to obtain precise 2000 point models based on vertebral body descriptors.

SUMMARY

The presented approach allowed very fast 3D-reconstruction of scoliotic spines based on few information on the X-rays combined with a priori knowledge obtained from morphometric databases. Because 3D reconstructions are quite similar to those obtained in a long thorough manual
process including iterative control, stereo-radiographic 3D-reconstruction of the spine in clinical routine is now possible.

REFERENCES

Deschênes, S., deGuise J. et al. . SPIE 2003 (accepted).