moreau piper segmentation

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A SEGMENTATION PIPELINE FOR THE CREATION OF STATISTICAL SHAPE MODELS IN THE PIPER PROJECT

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Introduction

While Human Body Models (HBMs) based on the finite element method have shown their usefulness in automotive safety, they are typically only available for a few sizes (e.g. average male). One aim of the PIPER project is to develop tools to better describe the population variability with such HBM. To this end, Statistical Shape Models (SSMs) of the full skeleton are being developed using a database of CT-based scans of 100 anatomical subjects. The present work aims at evaluating explored segmentation approaches for the SSM development.

Methods

Full body CT-scans acquired in overlapping sessions (head, trunk, lower limbs, voxel 0.97x0.97x0.5mm) were segmented using (A) semi-automatic tools (e.g. Slicer3D, ScanIP) (B) image-to-image registration (Elastix) to transfer a labeled reference mask and (C) model-to-image registration. For (C), the idea is to align an atlas reconstructed from one subject (Fig. 1) with target CT-scan from other subjects. The alignment is driven by a simulation using SOFA framework [1]. Two CT-scans (reference with atlas, target) are used. The user, to avoid incorrect registration due to pose variability in subjects, guides the deformation interactively. Segmentations from (A) were used to define the atlas in (B) and (C). Evaluation criteria included time to generate meshes and their suitability for SSM [2] i.e., accuracy and correspondence.

Results

Four full body scans were segmented semi-automatically. While it was relatively fast for long bones, it proved too lengthy for vertebrae and ribs as they can be poorly separated in elderly subjects. Image-to-image registration was applied to one subject and was promising. However, it required removing the scanning environment semi-automatically and merging the overlapping scans. An automatic merging process (C++/ITK) was developed and tested on 15 subjects.
Model-to-image registration was successfully used with 25 CT-scans to generate registered meshes of thorax, spine, pelvis and lower extremities. This efficient approach (1 hour/subject) provided meshes that are accurately registered (Fig. 2) and with point matching between subjects. This is important for SSM as it may remove additional correspondence process.

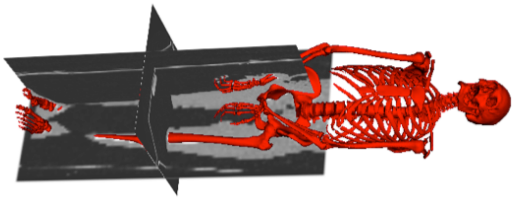

Figure 1: Red surface mesh: atlas used to perform the registrations.

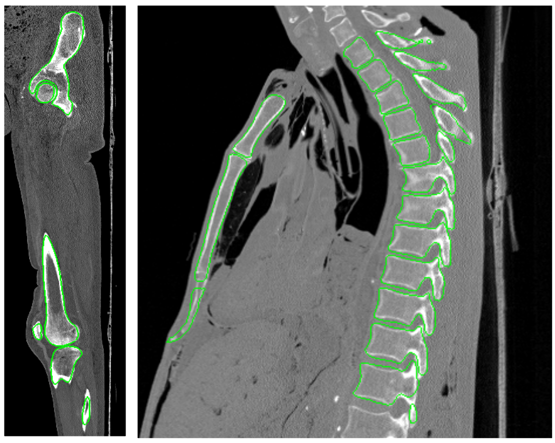

Figure 2: The green registered surface projected on a slice of the target PMHS CT-scan. Left: pelvis, lower limb. Right: sternum, thoracic vertebrae. Accuracy of registration: a Dice coefficient of 0.91 for a femur.

Discussion

Model to image registration was selected as the most promising approach to achieve both efficiency and accuracy. Adjustments are ongoing prior to its broad application including the articulation of some segments (e.g. extremities) in the SOFA simulation and the inclusion of landmarks in the reference model. All models and associated SSMs will be publicly released at the end of the PIPER project.

References

1. Gilles, B., Reveret, L., & Pai, D. K. (2010) and https://www.sofa-framework.org.
2. Cootes, T.F., *et al.* (1995)

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