Build Spine Atlas from Sparse Data

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INTRODUCTION

Statistical atlas is a 3D medical image analysis tool that includes information on geometry and function of populations, and their variations. We have developed a two-level method to build statistical atlases for femur in [1] based on the 3D non-rigid registration approach developed by Chui et. al.[2]. Our two-level method requires 3D high resolution surface data obtained from CT-scanned images using Marching Cube algorithm.

Compared with femur, spine vertebra has a much more complicated shape that is hard to segment from CT images using Marching Cube algorithm. We propose a semi-automatic approach to generate the high-resolution aligned surfaces by combining segmentation and registration in the same procedure.

METHODS

In our example we use lumbar vertebrae since lumbar vertebrae are the largest segments of the movable part of the vertebral column, it is easier to segment this section from the vertebral column. We select five lumbar vertebrae (L1-L5) and the last thoracic vertebra (T12) in our Experiment.

We collect 6 spine CT images (in DICOM format) in ICAOS (Institute for Computer Assisted Orthopedic Surgery, Pittsburgh, PA, USA)'s database. Half of them are from human being; others are from artificial spines with human size.

We first trim each CT images into small files with individual vertebra. We manually label about 250 surface points for each DICOM file. We also have a high-resolution 3D surface of vertebra generated by triangulating 40682 points which were carefully labeled by hand. Then we apply a procedure combining the registration and segmentation to generate high-resolution aligned surfaces (key steps are listed in below).

Step 1: Simplify the high-resolution reference surface to the low-resolution surface using the method de-scribed [3].
Step 2: Register the low-resolution reference to 250 labelled points using Chui's TPS-RPM method described in [2].
Step 3: Refine the low-resolution registration using a global deformation. We use another RBF based interpolation by an iterative way to warp the high-resolution registered reference surface toward to original low-resolution points. We employ the same RBF functions explained in [1] but different sigma for the RBF kernel. Here we choose sigma as 250. The larger sigma constraints represent the global deformation.
Step 4: Interpolate the low-resolution registration to high-resolution using RBF functions described in [1].
Step 5: Refine the high-resolution registration using global deformation described in Step 3 again. Local deformation described in [1] cannot be applied here since the high-resolution surface does not exist.

Finally we will obtain the high-resolution surface for each DICOM file which is already aligned with the reference surface and apply principal component analysis (PCA) to solve for the eigenvectors of the atlas.

RESULTS

The atlas population consists of 3 patients and 3 artificial spines, 36 spine vertebrae. By applying semi-automatic segmentation and registration method, we obtain much smoother and high-resolution vertebra surfaces from only 250 initial points. After PCA decomposition, we noticed that only 10 modes are needed to keep 95% of shape variation. The first mode encodes 39.0% of the shape variation, the second mode encodes 20.4% of the shape variation, and the third one has 12.8% of the shape variation.

CONCLUSIONS

Our work focuses on a new methodology to segment and register the spine surface from CT-scanned images. Experimental results show smoother surfaces than what Marching Cube algorithm does. Since it is a semi-automatic algorithm, it is much more efficient than segmenting data manually.

REFERENCES

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