3D Detection, Identification, and Segmentation of the Cervical Spine

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Image segmentation of the spine is crucial in the medical field, since being able to properly isolate areas of interest within spine scans can help identify key features such as fractures and dislocations. Segmentation of the spine can be grouped together with detection and identification of the vertebrae of the spine. Detecting and identifying the vertebrae prior to segmentation is beneficial as it allows for the segmentation of specific vertebrae. Many studies cover some subset of the tasks stated above, but very few have done all in one automated flow. There has been one study that covers all three major tasks in one automated process for the spine by Klinder et al [1]. Nonetheless, the study was done on scans of the whole spine and not exclusively on the upper set of vertebrae in the spine known as the cervical spine. This difference needs to be accounted for as there are more identifiers, including the sacrum, present only in the complete spine. It is desired to segment the cervical spine to be able to detect for cervical fractures and dislocations in future studies. The cervical dataset used contains approximately 9800 studies of cervical spine computed tomography (CT) scans, with approximately 1000 fractures present. There has also been a study done on segmenting the lumbar spine, which constitutes the lower end of the spine, by Rasoulian et al [2]. This study uses a statistical multi-object shape model detection, but it is to be noted that the lumbar vertebrae are larger than cervical vertebrae. This initial investigation into the cervical spine segmentation showed that there was a need to formulate a solution, potentially by altering pre-existing solutions. Hence, the problem that I will be addressing is the 3D detection, identification, and segmentation of cervical spine vertebrae, obtained from CT scans. The individual vertebrae from the cervical spine CT scan will first be detected, then identified (with the labels C1-C7), and finally segmented, to produce a 3D model.

Segmenting the cervical spine requires some pre-processing on the spine curve (i.e., the line that approximately follows the midpoint of each of the vertebrae). The spine curve is detected by putting a spline through the vertebrae to obtain the spine curvature. Next, we apply some rotational transformations to the spine through a procedure called Curved Planar Reformation (CPR) [3] such that the spine appears straight for orthogonal planes passing through the spinal axis. The process of segmenting the cervical spine involves a few major steps: detection, identification, and segmentation. For detection, we will use the Generalized Hough Transform (GHT) [4], a more powerful version of the Hough Transform (HT). The HT is used for detecting lines and other curves on an image by mapping the slope and y-intercept of each detected line on an image. The GHT extends the HT and allows for undefined parameters to create a table which, is then used as a reference for detecting similar images. The GHT is used by Schramm et al [5] for the detection and segmentation of 3D anatomical objects. Schramm carried out some pre-processing to limit the resources required as the GHT can be computationally expensive. The identification will be done by detecting the atlas (C1, the upper most vertebrae of the cervical spine) and by labelling the following vertebrae appropriately from C2 to C7. The atlas is used as an identifier as it is smaller than the rest and has a differentiating form. The method used for the segmentation is the triangulated surface meshes, introduced by Weese et al [6]. Weese balances the surface mesh between a priori data and the current scan that is being worked on.

This study can be used to classify for fractures or other disorders present in the cervical spine. It can also be used for similar detection, identification, and segmentation of other subsets of the spine as well as other bone structures or organs if the models for training the GHT and segmentation are altered to the corresponding structure.

References

[1] T. Klinder, "Automated model-based vertebra detection, identification, and segmentation in CT images," *Medical Image Analysis*, vol. 13, no. 3, pp. 471-482, June 2009.

[2] A. Rasoulian, "Lumbar Spine Segmentation Using a Statistical Multi-Vertebrae Anatomical Shape+Pose Model," *IEEE Transactions on Medical Imaging*, vol. 32, no. 10, pp. 1890-1900, October 2013.

[3] T. Vrtovec, "Automated curved planar reformation of 3D spine images," *Physics in Medicine & Biology*, vol. 50, no. 19, 14 September 2005.

[4] D. Ballard, "Generalizing the Hough transform to detect arbitrary shapes," *Pattern Recognition*, vol. 13, no. 2, pp. 111-122, 1981.

[5] H. Schramm, "Toward fully automatic object detection and segmentation," *Medical Imaging*, vol. 6144, no. 2, 2006.

[6] J. Weese, "Shape Constrained Deformable Models for 3D Medical Image Segmentation," *Information Processing in Medical Imaging*, pp. 380-387, 2001.