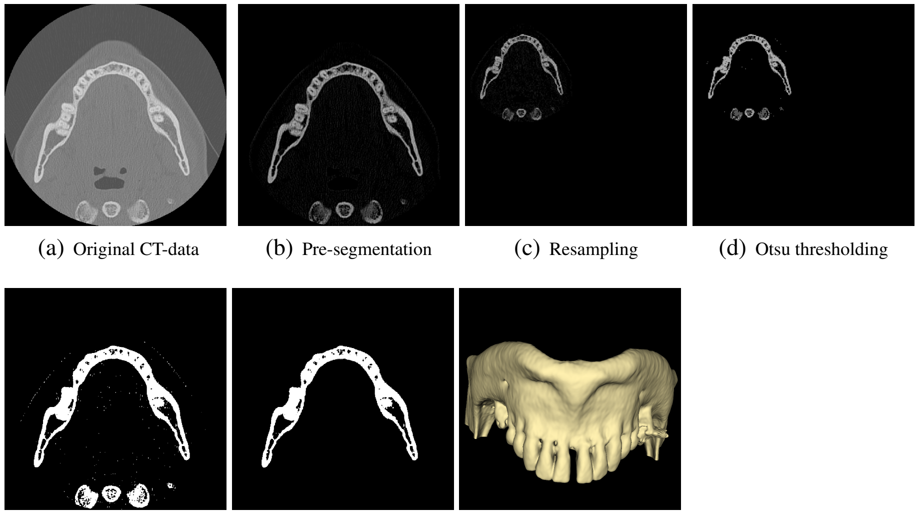
A fast and automatic segmentation of the mandible for CT-data

1 Purpose

The increasing popularity of dental implant surgery has recently motivated the development of new computer-assisted systems and methods to assist the dentist in the clinical procedures. Optimal implant placement can be planned on a three-dimensional reconstruction of the patient mandible, which is obtained by segmented CT-data. Such segmentation is typically performed by a simple manual thresholding of the dataset, with the drawback of generating many small structures which may hide the mandible. Others propose manual segmentation, histogram equalization or deformable models. Those process can be cumbersome and time consuming. In this paper we present a new procedure to extract the contour of the main mandibular structures (lower or upper jawbone) from CT-data. In order to provide a practical and efficient solution to the clinicians, we propose an automatic and fast segmentation method.

2 Methods

Our method is based on automatic multiple thresholding followed by a region-growing algorithm to extract the object of interest. In a pre-processing, we apply an automatic thresholding in order to normalize the background noise into a single intensity value (Fig. 1(b)). A further step consists of resampling the dataset, to speed up the automatic segmentation. In order to preserve the quality of low resolution images, we define a heuristic rule to resample the image depending on the original size. The reduction in x- and y-direction corresponds in each case half the image dimension. For the z-direction we created an algorithm depending on the resolution of the original image. When the image contains less of 50 slices, no resampling is performed. Otherwise, the downsampling factor is equal to 2 in case of 50 to 149 slices, 3 in case of 150 to 249 slices, and 4 in case of more than 250 slices (Fig. 1(c)). Once the image has been resampled, the multiple threshold method by Otsu is applied to compute the threshold values. The Otsu method aims at selecting the thresholds by maximizing the between-class variance and minimizing the inter-class variance. The best result was achieved by an adjustment of a number of three threshold classes, where the first one represents the mandible (Fig. 1(d)). At the end of the segmentation pipeline we segment the object with a binary threshold filter and the computed values of Otsu. The input of this filter is the original dataset (Fig. 1(a)) and the threshold of the mandible. The result is a binary image mask which represents the mandible (Fig. 1(e)). The extraction process of the object of interest is based on a region growing method. The brightest point in the image is taken as the seed point of the algorithm. The resulting object is defined as a single connected component containing the brightest point. In some cases, the component might



(a) Original CT-data (b) Pre-segmentation (c) Resampling (d) Otsu thresholding

(e) Binary thresholding (f) Object extraction (g) $3D$ Reconstruction

Fig. 1. Segmentation of the Mandible.

represent other objects different from the mandible, for example crowns of the other jawbone. In order to be able to identify such cases, we implemented a rule based on the component volume and is defined by the largest object in the image. The volume is calculated using the binary image of the resulting segmentation, counting the object voxels and multiplying the sum with the voxelspacing. When the volume is less than an empirically defined threshold, a connected component filter is called to correct the result. The filter labels the object of a binary image. We assume that the algorithm designates the largest object with the first label and can be extracted by using a threshold filter with the highest and lowest threshold of the label value (Fig. 1(f)). The resulting binary mask of the segmentation is used to reconstruct the three-dimensional model of the mandible (Fig. 1(g)). Our application was written in `C++` using the `ITK` and `VTK` libraries for image processing, as well as `QT` for the interface.

3 Results

The procedure was tested on 12 datasets of different resolutions and acquired by different CT devices. To evaluate rapidly the results of the segmentation, a plane widget is provided showing the slice of the original dataset mapped on the clipping plane of the three-dimensional reconstruction. High-quality mandibular segmentation was obtained by all datasets, with accurate definition of the bone contours and removal of undesired objects. An average computational time of 1:57s per dataset is achieved on a standard PC (Intel Pentium 3.40GHz with 1GB of RAM). The resample filter allows to improve the calculation time by a factor of 4.74. The filter resampled an image of the size of 512x512x46 to 256x256x46, while preserving a reasonably good quality of the image.

An image of 485x485x241 is downsampled to 242x242x80 and reduces the computational time by a factor of 5.14 (computational time of 10:84s to 2:11s). In only one of the 12 datasets it has been necessary to call the connected component filter.

4 Conclusion and Perspectives

The results of our automatic segmentation process has proved satisfactory for all tested dataset. The computational time is mainly less than 2 seconds, which is a very good result of a segmentation process for a computer-assisted system without any interaction of the user. The inclusion of an automatic control based on components volume makes our extraction method particularly robust. Moreover, a manual threshold correction has been integrated in the interface to correct the segmentation in case of failure. Future work will be an automatic segmentation of the teeth and the nerves, which will be based on in this paper presented segmentation process.