Virtual Teeth: A 3D method for editing and visualizing small structures in CT scans

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Abstract

This paper presents a new interactive method for segmentation and visualization of small structures in CT scans. A combination of iso-surface generation, spatial region growing and interactive graphics tools are used to extract small structures interactively. A practical example of segmentation of the dentition in a CT scan is shown.

1. INTRODUCTION

A number of congenital craniofacial anomalies involve severe disturbances of tooth formation and eruption (eg. cleidocranial dysplasia, tricho-dento-osseous syndrome, and Apert syndrome). So far, studies of these dental problems have been limited to two-dimensional analysis from orthopantomograms, intra-oral X-rays or cephalometric radiographs.

The present paper presents a new method for visualization of the developing tooth crowns in three dimensions based on CT scans of the jaws. The dentition is segmented using a combination of manual editing and threshold selection, and iso-surfaces generated by an algorithm similar to the Marching Cubes algorithm [Lorensen et al. 1987] are subsequently rendered on a Silicon Graphics workstation.

Since the iso-surface algorithm produces a large unstructured set of small polygons we have developed a post-processing algorithm that finds and separates connected components in the scene. This allows us to interactively pick out individual elements such as the teeth and noise fragments and either delete them or change their properties.

2. METHODS

The complete algorithm is illustrated in figure 1. It consists of 3 steps: Iso-surface generation, connected components separation and 3D object editing. All 3 steps are performed interactively and recursively.

To generate the iso-surface we have applied two iso-surface generation algorithms in the tradition of the Marching Cubes algorithm [Lorensen et al. 1987]. The first is an algorithmic improvement of the original Marching Cubes algorithm

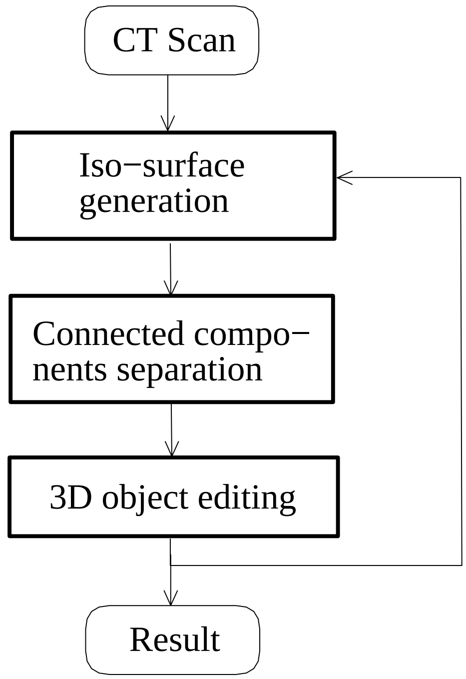

Figure 1: Algorithm for interactive segmentation and visualization

[Liversage et al. 1992] and the other is the 'soft object' algorithm [Wyvill et al. 1986]. We have not formally compared the quality of the two algorithms, but have been unable to find any visual differences. Although the first is simpler to implement and faster, it has the disadvantage that it is protected by a patent.

To find connected components in the unstructured output of the iso-surface generation algorithm, we apply spatial region growing to the resulting set of polygons. The region growing process works by iteratively finding non-processed polygons in the set of surface polygons and growing out from these polygons by including neighbouring polygons until no free polygons remain. The result is a set of connected polygons, each defining an isolated structure in the 3D scene.

Because the scene now consists of a structured set of isolated components, it is possible to edit the 3D scene using interactive graphics tools. Typical operations consist of removing noise and other components without interest, selecting individual teeth and changing their color to reflect function, selecting the cranium and making it transparent etc. Notice that these operations are only possible because of the previous connected component separation step.

3. RESULTS AND CONCLUSION

Figures 2-4 show the application of the method to visualization of teeth in connection with the diagnosis of an anomaly prior to surgical treatment. The iso-surface was generated from CT scans with a slice thickness of 2mm. Figure 2 shows the

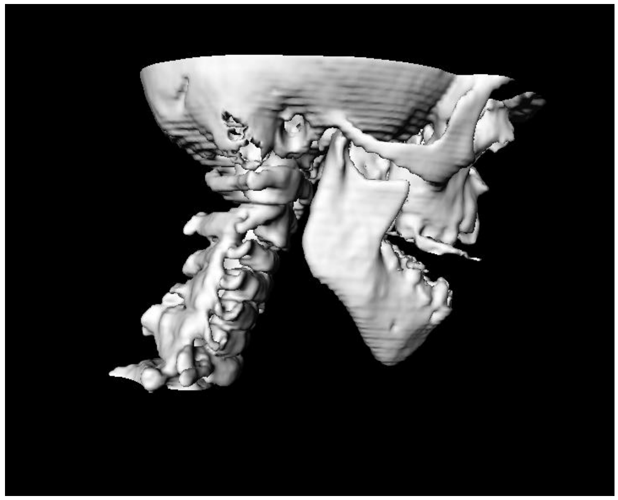

Figure 2: Initial result of iso-surface algorithm

initial result of the iso-surface algorithm before region growing. In figure 3, region growing has been applied to the iso-surface polygons and one component (the skull) has been made transparent. Figure 4 shows that it is now possible to edit individual structures in the scene.

All the tools have been implemented in the software package Mvox [Bro-Nielsen 1996] and the entire algorithm can be performed interactively. Using this software and the method described here, it is now possible to visualize and edit individualized sets of small objects found in iso-surface renderings generated from CT scans. [Kreiborg et al. 1996] describes the application of this method to analysis of tooth formation and eruption in the case of Apert syndrome.

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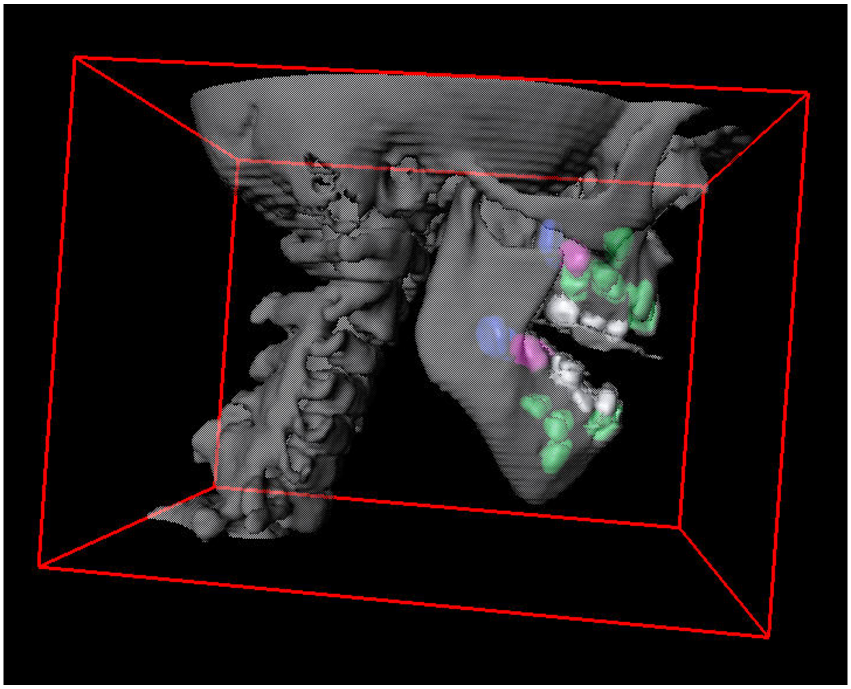

Figure 3: Result after spatial region growing.

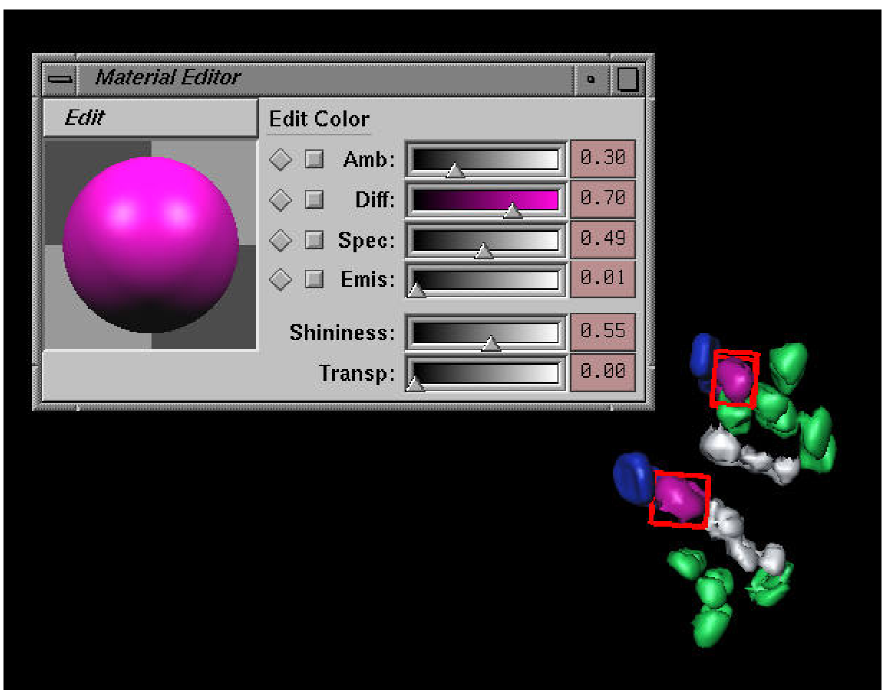

Figure 4: Editing small structures.