Prototyping a Planning System for Orbital Reconstruction

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Abstract. In the practice of maxillofacial surgery, one major challenge is the correct reconstruction of malformed or damaged bone structures of the face. Among those, a rather frequent task is the remodeling of an injured orbit to be symmetrical to the intact one. Here, the main difficulty of this intervention is the necessity to plan the repositioning of bone fragments as to achieve symmetry. In this paper we present a computer-aided method for planning orbital reconstruction. A new software tool has been developed, which provides facilities for processing and displaying volume datasets. Moreover a symmetry plane in 3D can be defined using a specialized user interface. Based on this symmetry information, parts of the anatomy can then be highlighted and mirrored. This facilitates the comparison of structures in the two halves of the patient's face.

1 Introduction

Injuries of the orbit occur frequently as a result of various types of accidents. A malformed orbit causes one eye to be displaced from a position that is symmetrical to the eye in the healthy half of the face. This can make the face look unesthetic and can also impair the function of the eyes, resulting in problems with the patient's vision. Figure 2(a) shows an example of a patient with one displaced orbit.

In order to reconstruct an injured orbit, bone pieces are removed from the skull of the patient. These are then placed in the damaged orbit so that a more symmetrical placement of the affected eye is achieved. The result of such an intervention can be seen in Figure 2(b).

2 Current State of Research

Up to now orbit reconstruction interventions have mostly been planned manually by the surgeon. In this process, the target positions for symmetrical features are

Fig. 1. A case of a patient with an injured orbit

(a) Before the intervention (b) After the intervention

marked on single 2D slices. The image data used as the basis for the planning is acquired in advance by a CT scan. Unfortunately, this procedure is quite time-consuming and can be inaccurate.

Benz et al. presented in 2002 a system for supporting orbit reconstruction [1]. Their method allows automatic generation of a symmetry plane and computation of the mirrored eye position. Since their work is based on the surface acquisition from an optical 3D scanner, it is not primarily aimed at working with bone structures. Recently their system has been extended for additional visualization of image slices from a volume dataset [2].

Also in 2002, Gellrich et al. introduced their method for planning post-traumatic orbital reconstruction [3]. Their approach includes a planning stage on 2D slices from a CT dataset. The resulting plan can later be imported into an intra-operative navigation system and visualized in 3D.

3 The new Software Tool

We have designed and developed a prototype for a computerized planning system for orbital reconstruction. The system provides facilities for loading different types of volume data (e.g. DICOM). Once a volume dataset has been imported, the symmetry plane can be defined manually through an intuitive user interface. In order to do so, the user only has to draw two lines, one in the axial and one in the coronal slice display. The lines are assumed to lie on the symmetry plane and are sufficient for determining the plane with five degrees of freedom. The user interface is shown in Figure 3.

The surgeon can then mark relevant bone features in the volume dataset. Functionality to mirror them by the symmetry plane is provided by the software. These features are illustrated in Figure 3. The entire planning session can then be exported as a xml-file, or as a volume dataset.

Unlike earlier approaches, our system is not limited to working on the original volume dataset delivered by the scanning procedure. As described below, our software performs a threedimensional geometric transformation of the data according to the given symmetry plane. This enables us to also work on cases in

Fig. 2. Definition of the threedimensional symmetry plane

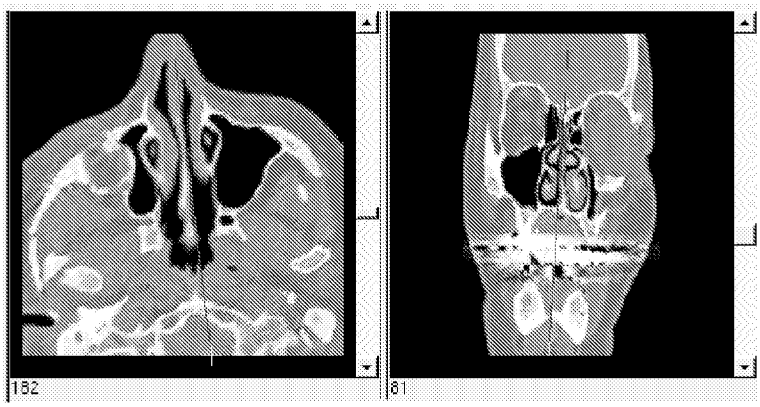
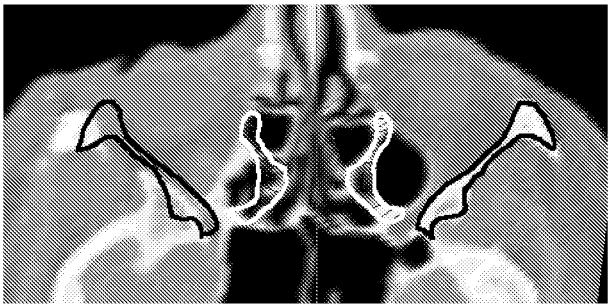


Fig. 3. Mirrored drawing on an image slice



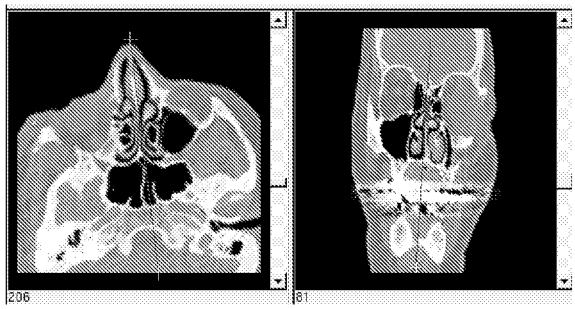
which the patient's head is not perfectly aligned in the volume. Given the degree of accuracy that we aim to achieve, this is almost always true.

4 Implementation

The software was implemented in C++, based on the Visualization Toolkit (VTK) and medical visualization components developed during the past years in our group. The symmetry plane is defined in 3D by combining the manual input of two symmetry axes in orthogonal slice views. An interactive rendering of the volume dataset together with the symmetry plane enables the assessment of the validity of the plane placement.

Thereafter, the volume is geometrically transformed, to achieve a vertical re-alignment of the symmetry plane to the y/z plane of the cartesian coordinate system. Due to this re-alignment, the mirrored drawings of the surgeon can be easily performed within the individual 2D slices, since the result will appear in the same 2D slice. In Figure 5(a), axial and coronal views of a volume dataset

Fig. 4. Adaptation of the volume with geometric transformations



(a) Original volume dataset

(b) Volume re-aligned according to the symmetry plane

before the re-alignment are shown. Figure 5(b) shows the slices with the same indices in the adapted volume. We also investigated fast methods for computing the geometric transformation and the resampling of the volume dataset. These are described in more detail in [4] and [5].

5 Results and Discussion

Our prototype system has been tested with several clinical cases requiring orbital reconstruction. An introduction into the clinical practice is planned in the near future.

Early assessment of the software indicated that it will enable a significant reduction of the time required for planning orbital reconstruction interventions. Due to the three-dimensional paradigm pursued in this approach, it also provides a higher accuracy and extra information compared to previous methods. We also intend to add functionality for displaying volume differences and transferring the planning sessions to an intra-operative navigation system.

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