Restoration of the lost volume of bone tissue with use data of the computed tomography

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Abstract. The paper deals with the issue of bone tissue restoration. To assist the specialist, we developed the SmartAssistantConstructor software package. The recovery process is based on finding a mirror copy of a piece of bone tissue. The article describes the algorithm for finding the missing part of the bone. The paper shows examples of this operation.

Introduction

As a result of oncology, injuries and infectious diseases, bone damage is possible, accompanied by inflammatory processes and leading to disruption of the live. As a result of the removal of a portion of bone tissue, a person most often becomes socially and physically limited. Particularly acute, this problem is expressed with the defeat of the bones of the skull. Such a lesion can lead to dysfunction of swallowing, smell, vision, hearing, etc. Reconstructive surgery allows you to return a lost area to a person. For the reconstruction of the function of the body and the creation of an implant, it is necessary to use specialized CAD systems or manual restoration. To obtain a model of the bone structure of the body without surgery on the body, most often use methods of computed tomography. The most effective approach to analyze the internal structures of the body is radiation diagnosis. The use of X-ray allows for the analysis of dense tissue with an accuracy close to the wavelength. Modern multi-slice tomographs allow high-speed shooting of a part of the human body, and modern software allows for the rapid construction of a three-dimensional structure.

When getting slices by computer tomographs, various distortions are superimposed on the slice images. These distortions interfere with subsequent operations and introduce additional errors into the construction of individual implants. The reason for the occurrence of interfering components may be: patient movement, electronics, sensory noise, the presence of metal in the body, etc. Methods of primary data processing are involved in eliminating errors. In the papers [1-3], approaches are considered which allow reducing both the noise component and reducing the amount of blurring present on the slices. Subsequent processing aimed at image analysis and allowing the identification, for example, considered in papers [4-5]. Identification of basic features and boundaries of bone tissue allows to increase the accuracy of building 3D structures, which subsequently will

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improve the accuracy of the fit of the implant to the area to be replaced. The accuracy of the fit directly depends on the speed of implant growth into the bone structure and, as a result, the time of adaptation of the person. In papers [6-7], the questions of constructing three-dimensional structures and their analysis were considered. When searching for a replacement tissue, there is an urgent need to automate the process, since the time for implantation greatly affects the quality of life. So when resecting part of the lower jaw, sagging of muscle tissue can be observed, and in the case of a long waiting period, a subsequent loss of flexibility can occur, which can lead to dysfunction of swallowing or speech. The ideal case is a quick construction, in which a fragment of the replaced tissue is produced during the to operation. Rapid implantation is possible only with the automation of both the design process of the implant and the production process. In this connection, the actual task is to automatically obtain an implant based on computed tomography data.

1 Structure and data preparation

As input data when building implants are the data obtained by computed tomography devices. The device generates DICOM format files that contain patient information (age, height, name, gender, etc.), information about the gland (sensor type, frequency and slice pitch, world coordinates, the spatial resolution of sensors, etc.) and slices (images of the internal structure of the object of study). To build an implant, most often, we need information obtained only from slices (images). The accuracy of building a three-dimensional structure depends on the quality of the preprocessing. In work, image processing is used by standard means provided by developers together with computer tomographs. Bone search is performed on standard ranges for the Hounsfield scale, in the range of 480-800 HU. An example of the data presented in Figure 1.

Fig. 1. An example of the CT data.

2 The algorithm to search for implants

The general algorithm for searching for a fragment of a missing bone tissue area is to perform the following basic operations:

1. Loading data. The data are presented in the form of images obtained by the step-by-step movement of the CT apparatus by obtaining sections of the density reflecting tissues located in the study area. For subsequent recovery, only CT images of the slices are used.
2. Preprocessing (denoising, deblurring, superresolution, selecting a range on a Hausfeld scale and etc.).

3. Creation of 3D bone. Based on the boundaries of objects of a given density on the Hounsfield scale, we determine the boundaries of the bone.

4. Removal of small elements of dense structures. This operation is performed in semi-automatic mode. The size of the removed grain is automatically set, but the specialist can increase the size in order to remove a larger quantity without fear of losing important elements.

5. Search or manual selection of reference points with symmetry (Cranimetric points).

6. Performing the mirroring operation for the structure by the position of base points. The result of the operation is a rough approximation to the existing bone structures. The approximation is rough since the skull is always non-symmetrical.

7. Transformations over the three-dimensional structure, allows you to combine all the basic points and boundaries of tissues. As a transformation algorithm, we used the analysis of a graph tree, whose nodes were points of object boundaries. For offset, the nearest neighbor search algorithm was used.

8. Search for the missing volume. This operation is performed using logical functions.

9. Elimination of the missing volume and the introduction of restrictions on the thickness of the borders. With small differences in the boundaries of objects, thin false leads may structure. In the software package, they are excluded on the basis of thickness.

10. Coarsening of the model and data conversion to stl model.

3 An example of performing algorithm

Figure 2 shows an example of performing the operations of the algorithm proposed in Section 2. The results were obtained using the developed software that allows searching for the missing volume in an automated mode.

Fig. 2. An example of the operation of combining.

Figure 2a shows an example of performing steps 3 and 5, figure 2b is an example of performing the mirroring operation step 6, figure 2c performing geometric transformations over the resulting mirror copy step 7.

Figure 3 shows an example of the result of subtracting the volumes obtained as a result of performing steps 6 and the search for the missing volume of bone tissue.

Fig. 3. An example of the result of subtracting the volumes bone.

Figure 3a shows the result of subtracting the mirrored and available volume. To minimize errors, we introduced the criterion for eliminating thin boundaries, which allows us to remove thin boundaries caused by the error of combining two volumes. Figure 3b shows an example of combining three structures is of bone, soft tissue and the volume being replaced.

4 Conclusion

In this paper, an algorithm for searching for the missing bone tissue volume has been developed. The resulting algorithm is implemented in the form of independent software SmartAssistantConstructor that allows performing basic operations in an automated mode. The operation of searching for the missing volume is implemented using the algorithm of searching for a mirror copy, which will be ineffective if there is no symmetry of the bone tissue.

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