ALGORITHM OF LAYER MODEL

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S u m m a r y

The paper characterizes the method of layer model building, basing on the computer tomography images, which can be used in the reverse engineering and rapid prototyping systems. The method of layer model building does not use STL (stereolithography) format as the interface between CAD (Computer Aided Design) software and the rapid prototyping machines. It gives opportunity for cost reduction of CAD software, because the software does not require the complicated algorithms for mesh (triangular facets) creation basing on the model sections, which were acquired by computer tomography apparatus.

Keywords: rapid prototyping, computer tomography

Algorytm budowy modelu warstwowego

S t r e s z c z e n i e

W artykule przedstawiono opracowany algorytm budowy modelu warstwowego, wykorzystujący obrazy uzyskane metodami tomografii komputerowej. Algorytm jest stosowany w systemach inżynierii odwrotnej i szybkiego prototypowania. Algorytm nie używa formatu STL do wymiany informacji pomiędzy systemem CAD i urządzeniem do szybkiego prototypowania. Stwarza więc możliwość zmniejszenia kosztów oprogramowania CAD. Nie wymaga stosowania skomplikowanych algorytmów tworzenia powierzchni fasetkowych na punktach przekrojów modelu, uzyskanych podczas analizy obrazów tomograficznych.

Słowa kluczowe: szybkie prototypowanie, tomografia komputerowa

1. Introduction

The reverse engineering technology gives possibility for constructing the object basing on the material model – without traditional designing [1]. The paper presents the two aspects in the reverse engineering – reconstructing the object basing on the series of computer tomography (CT) images and building the material model using the original layer method.

The described method of layer model building does not use STL (stereolithography) format as the interface between CAD (Computer Aided Design) software and the rapid prototyping machines. It gives a chance for cost

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reduction of CAD software, because the software does not require the complicated algorithms for mesh (triangular facets) creation basing on the model sections, which were acquired by computer tomography apparatus.

The first step in traditional reconstruction of object basing on the computer tomography images is the detection of model's edges. This problem is described in detail in the article [2] and the monograph [3]. The results of edge detection is the set of model sections. The model's sections are the base for constructing the virtual model using the triangular facets. The obstacles in algorithm for facets building are shown in Fig. 1.

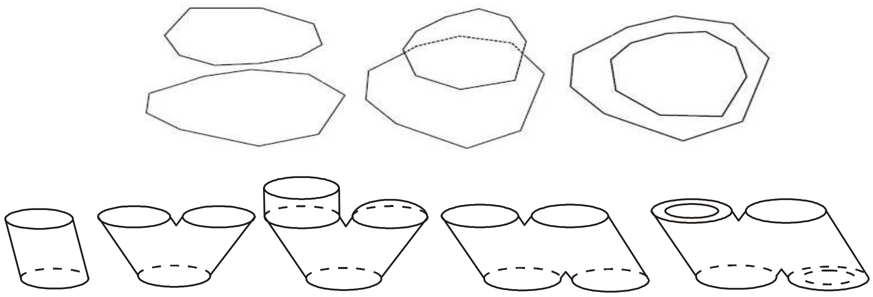

Fig. 1. Types of sections' interdependence [3]

The algorithm has to analyse the sections interdependence and build the complicated facets (e.g. the bottom right example – the two connected tubes with holes). The constructed facets structure can be converted into STL format, which can be sent to RP software. The above example shows, that the typical algorithm is very complicated – it means, that it is very expensive.

Another ways for model building are shown in bibliography.

Liu, Wong, Zhang and Loh [4] propose an error-based segmentation approach for direct rapid prototyping (RP) of random cloud data. By constructing an intermediate point-based curve model, a layer-based RP model is directly generated from the cloud data and served as the input to the RP machine for fabrication. In this process, neither a surface model nor an STL file is generated. This is accomplished via three steps. First, the cloud data is adaptively subdivided into a set of regions according to a given subdivision error, and the data in each region is compressed by keeping the feature points within the user-defined shape tolerance using a digital image based reduction method. Second, based on the feature points of each region, an intermediate point-based curve model is constructed, and RP layer contours are then directly extracted from the models. Finally, the RP layer contours are faired with a discrete curvature based fairing method and subsequently closed to generate the final layer-based RP model. This RP model can be directly submitted to the RP machine for prototype manufacturing.

The above method has been presented by the same authors in another journal [5].

The algorithm similar to above method is described by Wu, Wong, Loh and Zhang in [6]. One of the innovative modeling methods is to directly slice the point cloud along a direction and generate a layer-based model, which can be used directly for fabrication using RP techniques. However, the main challenge is that the thickness of each layer must be carefully controlled so that each layer will yield the same shape error, which is within the given tolerance bound. The algorithm generates a direct RP model with minimum number of layers based on a given shape error. The method employs an iterative approach to find the maximum allowable thickness for each layer.

2. Algorithm of layer model

The author worked out the original algorithm for building the material model of object, basing on the CT images.

The cooperation between author and surgeons during the planning of craniofacial surgical operation has shown, that the only material skull model (without virtual model in CAD system) is needed in some cases (Fig. 2). It can be done by method, which is described below.

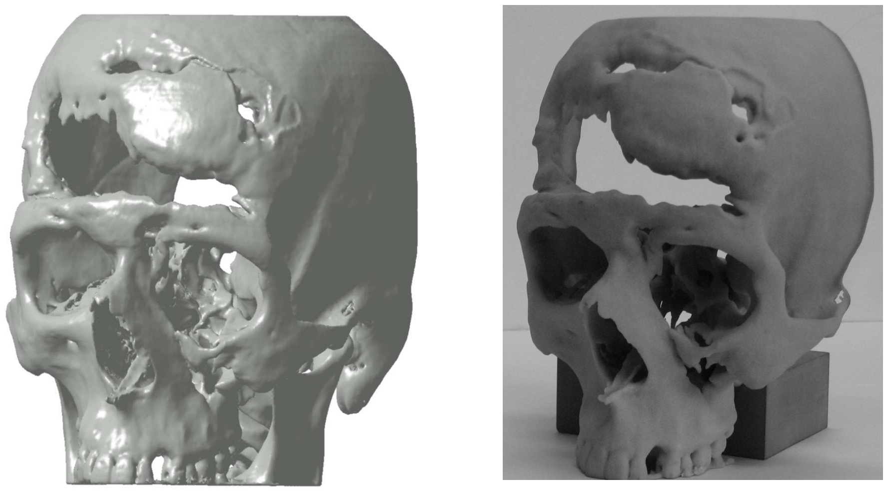

Fig. 2. Virtual and material models of human skull [3]

The material models are built using one of the incremental RP method, e.g. 3D-Printing. This method requires data, which describes the model layers with thickness such as printing layers thickness (Fig. 3).

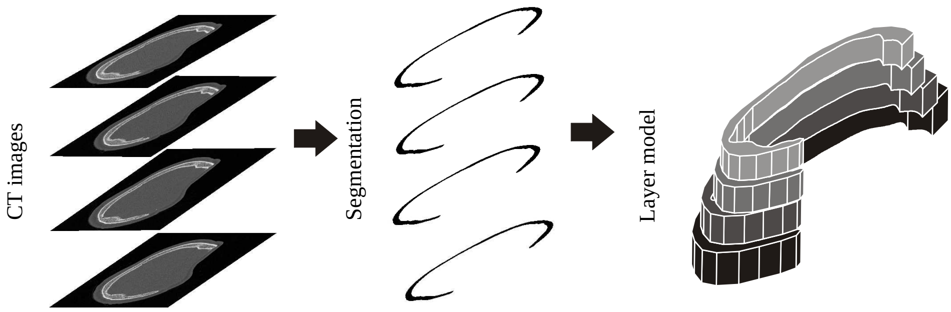

Fig. 3. CT images of object’s sections and layer model [3]

The edge detection is provided using the segmentation by binarization method [2, 3].

The problem of distance between printed layers should be discussed in this place.

The distance between CT sections (CT images) is more than 0,5 mm. The resolution in section plane (CT image resolution in XY plane) has similar value. The distance between printed layers should be less than 0,2 mm, because it gives a chance for good reconstruction of the model. It means, that the distance must be reduced. The interpolation method can be applied for resolving this problem.

The algorithm generates the quasi-CT images (additionally object sections) between acquired images. Moreover, the algorithm resizes the images to better resolution (Fig. 4). The calculation of additionally sections and images with better resolution is provided using the bilinear interpolation [7]. It is compromise between the calculation speed (it is feature of the nearest neighbour interpolation method [8]) and the image quality (quadratic or cubic spline interpolation [9]).

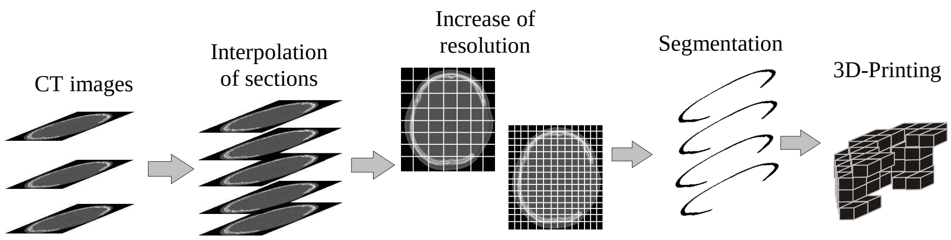

Fig. 4. Scheme of algorithm [3]

The lumination of interpolated point (L_0) is calculated basing on the neighbour points (L_1, L_2, L_3, L_4) (Fig. 5):

$$L_0 = L_1\left(1-\frac{\Delta x_0}{\Delta x}\right)\left(1-\frac{\Delta y_0}{\Delta y}\right) + L_2\frac{\Delta x_0}{\Delta x}\left(1-\frac{\Delta y_0}{\Delta y}\right) + L_3\left(1-\frac{\Delta x_0}{\Delta x}\right)\frac{\Delta y_0}{\Delta y} + L_4\frac{\Delta x_0}{\Delta x}\frac{\Delta y_0}{\Delta y} \tag{1}$$

Interpolation of additional sections between aquired images is the first step of algorithm (Fig. 6a). The images with assumed distance are calculated – it is the interlayer distance for 3D-Printing.

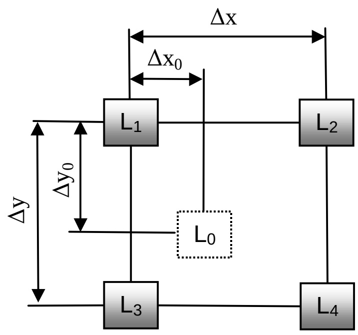

Fig. 5. Bilinear interpolation

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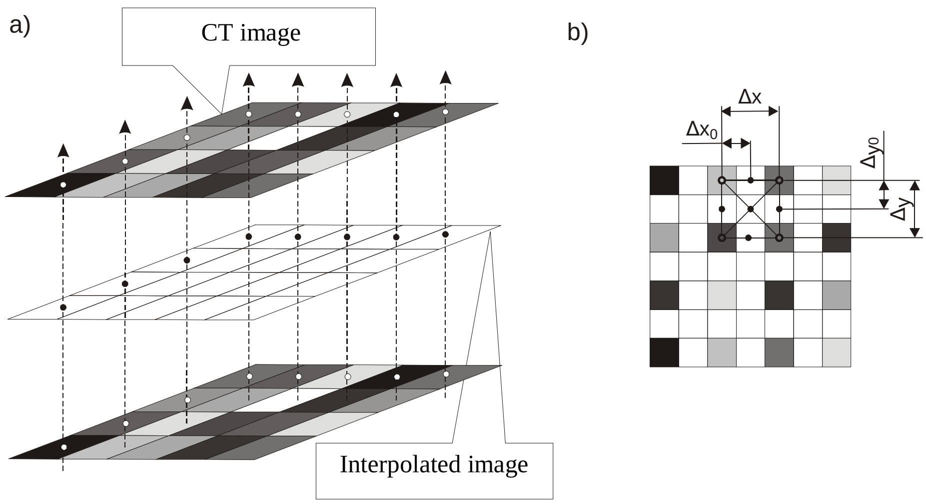

Fig. 6. Interpolation: a) between sections, b) images (resolution enlargement) [3]

The resolution increase is the next step of interpolation algorithm – the points with size, which is suitable for 3D-Printing are calculated (Fig. 6b).

The distance between layers and image resolution should be 2 times less then assumed resolution of material model.

The third step of algorithm is segmentation, which is done by binarization method (Fig. 7).

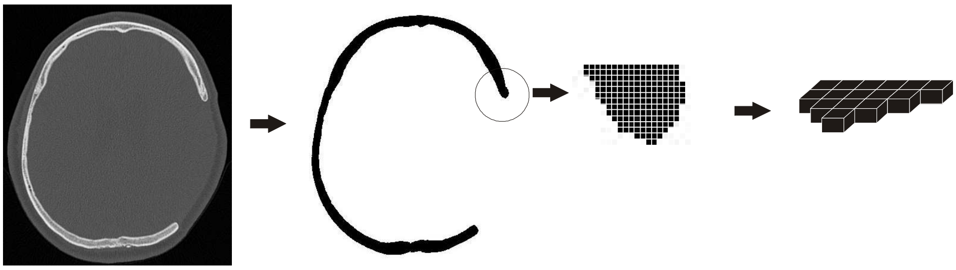

Fig. 7. Segmentation [3]

3. Conclusions

The described algorithm gives a chance for cost reduction in medical reverse engineering. The STL interface between CAD and RP system is not required. It means, that the material models can be constructed basing on the CT images, without expensive systems for edge detection and virtual model building, because the complicated facet model on object sections is not built.

Acknowledgment

The CT images have been done in Cracow University Hospital. The material models of skulls have been done in cooperation with Car Technology Sp. z o.o.

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Received in August 2011