

### 3D RECONSTRUCTION OF NMR IMAGES

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**Summary** This paper introduces experiment of 3D reconstruction NMR images scanned from magnetic resonance device. There are described methods which can be used for 3D reconstruction magnetic resonance images in biomedical application. The main idea is based on marching cubes algorithm. For this task was chosen sophistication method by program Vision Assistant, which is a part of program LabVIEW.

#### 1. INTRODUCTION

Computer rendering techniques have always concentrated on visualising simple primitive structures, more complex structures can then be created by combining these simple 'primitives' to shape a more complex model. Unfortunately the real world has never been very forgiving and some types of data do not translate very easily. The Marching Cubes algorithm was designed by William E. Lorensen and Harvey E. Cline to extract surface information from a 3d field of values. The input data set can represent anything from medical imaging data to geological scans.

#### 2. THEORETICAL MODELS

##### „The Marching Squares“ algorithm

To explain the algorithm let us first look at a 2 dimensional equivalent. In the Fig. 1 is shown a grid of squares equivalent to the cubes from the 3d algorithm (many people refer to the cubes as 'cells' or voxels). A solid circle has been drawn which is the shape we are going to approximate using lines (instead of polygons).

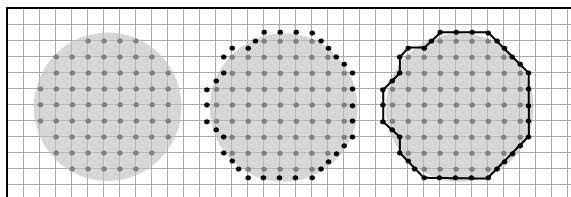


Fig. 1. Marching squares algorithm

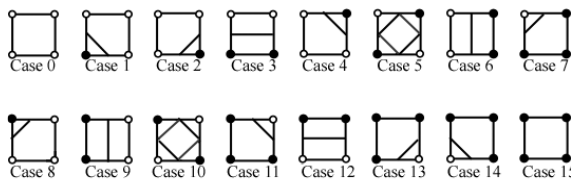


Fig. 2. All 16 squares combination

The first step is to calculate the corners that are inside the shape which are represented by the small grey dots (Fig. 1). We can now insert some vertices, since we know which points are inside and which are outside we can guess that a vertex should be positioned approximately halfway between an inside corner and any outside corners that are connected by the edge of a cell.

In the central diagram in the Fig. 1 is shown the discussed vertices as small black dots and the diagram on the right shows the matching surface formed by joining the vertices with lines [5].

There is 16 dots combination in one square as we can see in The Fig. 2.

##### The marching squares ambiguous cases

Marching squares algorithm can find out ambiguous result (Fig. 3). As you can see in the previous picture we are not able to take a decision on the interpretation of this kind of situation. However, these exceptions do not imply any real error because the edges keep closed.

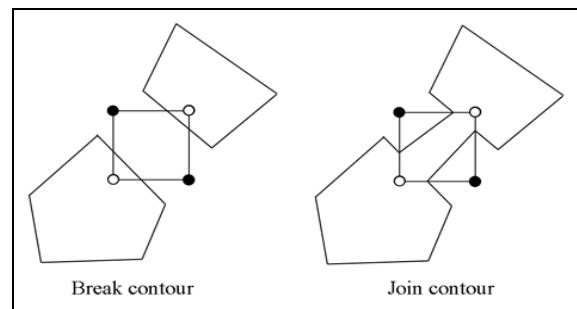


Fig. 3. Marching squares ambiguous cases

### „The Marching Cubes“ algorithm

Following the marching squares algorithm we can adapt our approach to the 3D case: this is the marching cubes algorithm. In the 3D space we enumerate 256 different situations for the marching cubes representation. All these cases can be generalized in 15 families and other is only rotation, symmetries (Fig. 4).

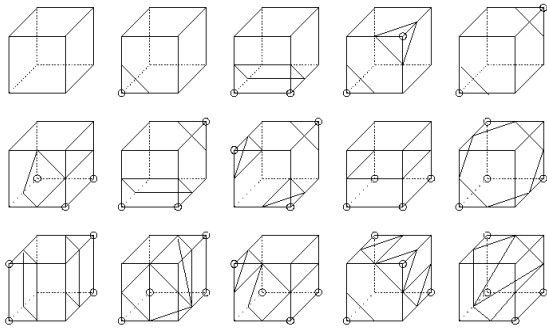


Fig. 4. Different 15 cubes combination

In the Fig. 5, 6, 7 are shown some sample outputs from the algorithm at 12, 20 and 50 subdivisions. This is equal to 1728, 8000 and 125000 cells respectively. The Sample density is essentially the number of cubes along each axis we intend to divide the volume into, this relates directly to the output quality. Since our test object occupies a roughly cube shaped volume of space this will be the same number of divisions along each axis.

In the Fig. 7 is shown the approximate shape of our test shape even at the lowest sampling frequency, we can see quite a bit of detail. Unfortunately we are also seeing the same kind of spatial aliasing as we saw in the 2D example; however this has shown us that the algorithm is working properly.

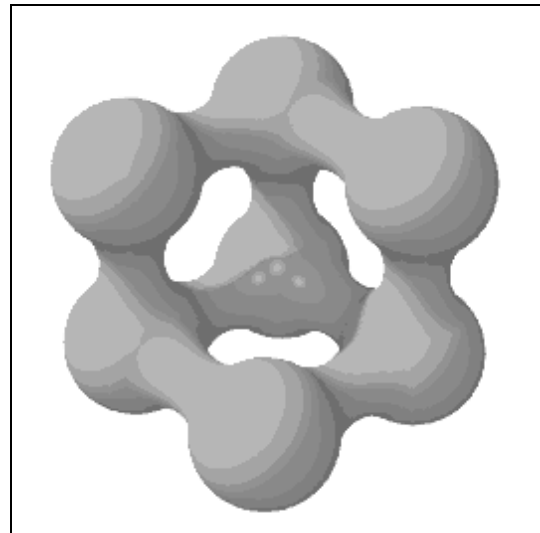


Fig. 5. Original shape

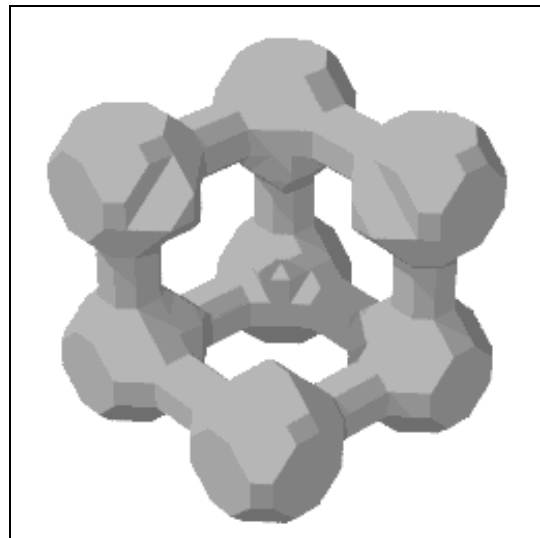


Fig. 6. Reconstructed shape, 12 subdivisions

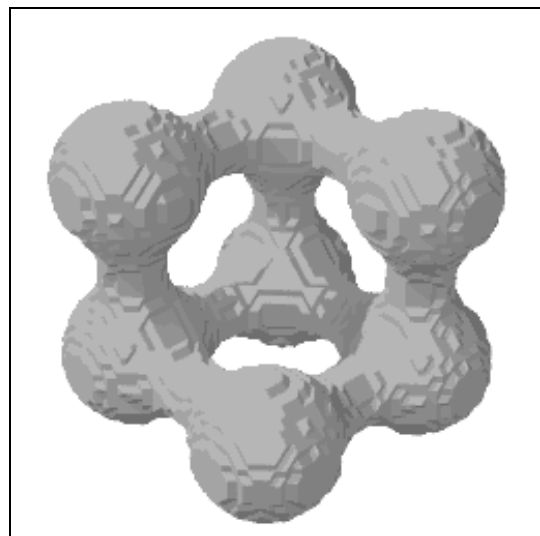


Fig. 7. Reconstructed shape, 50 subdivisions

### 3. EXPERIMENTAL RESULTS

NMR Images of head are obtained from Visible Human Version 2.0 [6]. This database contains very large database of NMR images in very high resolution therefore it is convenient for test algorithm. Resolution of scanned data is 230x230 pixels.

Reconstruction algorithm is implemented in LabVIEW with Vision Assistant module (Fig. 8.). In Vision assistant is written script for segmentation and processing of 2D images (filtrating, threshold). 3D reconstruction is written in program LabVIEW. Visualisation and rendering of final triangles is made in program POV-Ray.

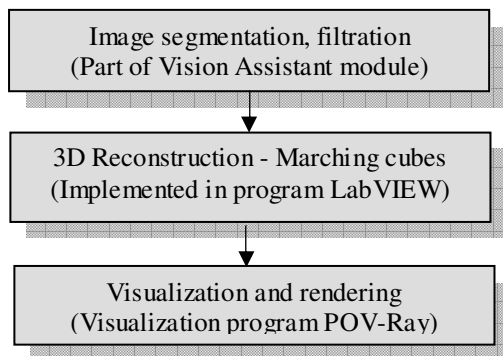


Fig.8. Algorithm of 3D reconstruction

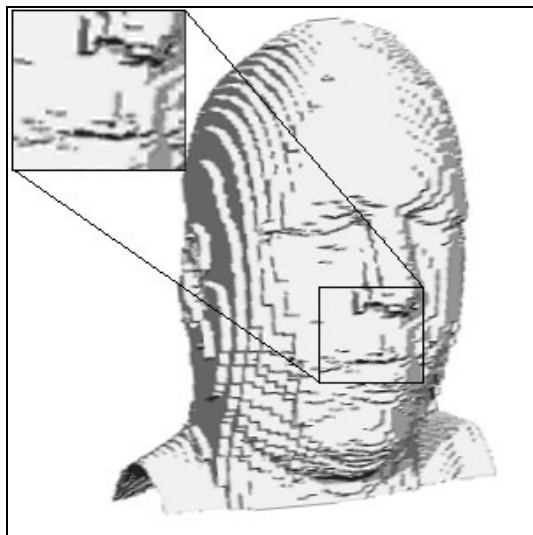


Fig.9. Head reconstruction of NMR, 54 subdivisions

In the Fig. 9 is shown 3D reconstructions of head from NMR in 54 subdivisions. We can see that a lot of details are lost, but time of reconstruction is 10 times faster like final reconstruction.

In the Fig. 10 is shown 3D reconstruction of head from NMR in 135 subdivisions. We can see that image is very similar to final image (Fig.11), but

speed of reconstruction is three time faster. Reconstruction of head is drawn 241 374 triangles (Tab. 1.).

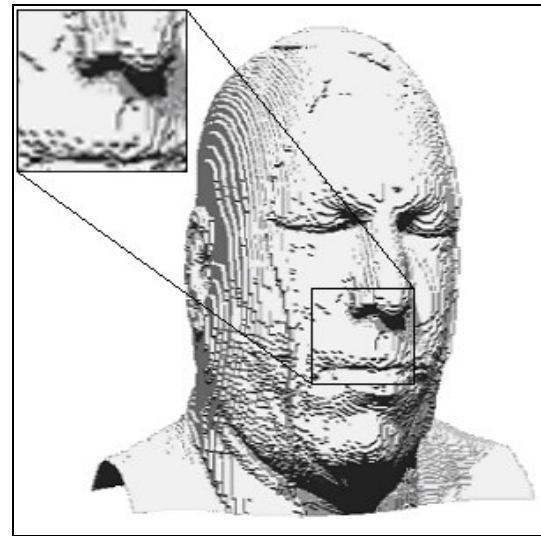


Fig.10. Head reconstruction of NMR, 135 subdivisions

In the Fig. 11 is shown final image, where 270 subdivisions are used. On head we can see detailed contour of head with maximum details of Magnetic resonance.

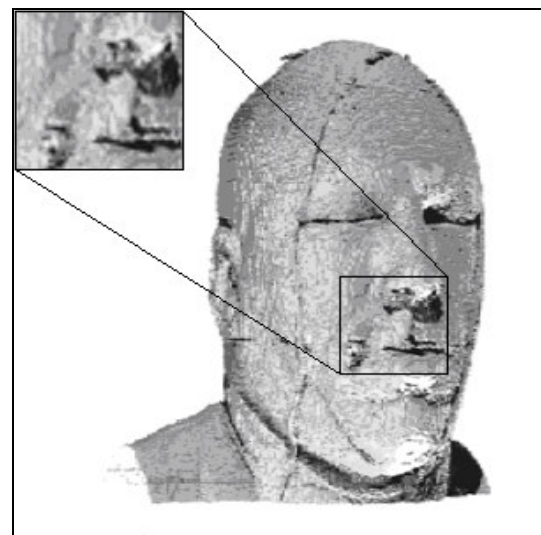


Fig.11. Head reconstruction of NMR, 270 subdivisions

Table 1. Measured value of reconstructed head

3D Reconstruction of head (230x230pix)			
figure	Fig.9	Fig.10	Fig.11
count of 2D slices	54	135	270
reconstr. time [s]	410	1037	3574
count of triangles	82 576	241 374	573 716

In the Fig. 12 and 13 are shown 3D reconstructions of scanned images obtained from Faculty Hospital Martin, division of radio diagnostic [7]. There is used the same algorithm as in previous experiment (3D Reconstruction of head).

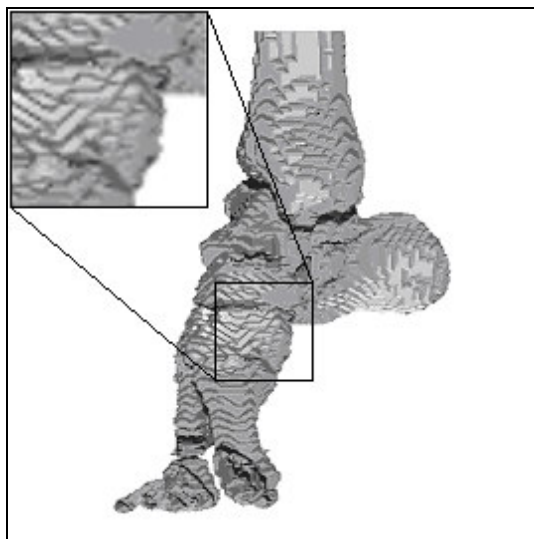


Fig.12. Leg reconstruction of NMR, 104 subdivisions

Reconstruction of leg in the Fig. 12 is built of 416 199 triangles and leg in the Fig. 13 is reconstructed from 76 205 triangles (Tab. 1.). We can see that a lot of details in the Fig. 12 are lost, but time of reconstruction is 5 times faster like reconstruction with 280 subdivisions.

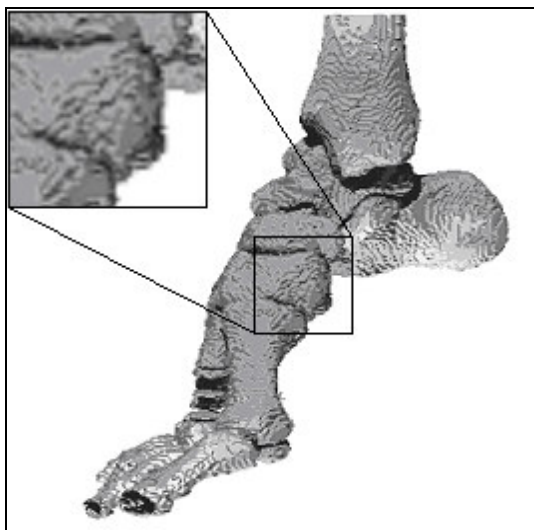


Fig.13. Leg reconstruction of NMR, 280 subdivisions

In Table 2 is shown 3D reconstruction information of each figure. In the first line is mentioned count of slices of reconstructed object and in the second line there is their resolution in

pixels. In the third line there is measured duration time of 3D reconstruction. Last line is resulted count of triangles of reconstructed object.

Table 2. Measured value of reconstructed leg

3D reconstruction of leg (170x180)		
figure	Fig.12	Fig.13
count of 2D slices	104	208
reconstr. time [s]	350	1520
count of triangles	76 205	416 199

#### 4. CONCLUSION

In this paper is presented methods for 3D reconstruction of biomedical images from NMR. The presented method is implemented in program LabVIEW. Presented NMR images of head were scanned from Faculty Hospital Martin and images of head are obtained from Visible Human [6].

The main addition of this work is implementation of mentioned method in program LabVIEW and module Vision Assistant. Experimental result in LabVIEW is comparable to conventional program as Matlab.

An advantage of presented method in this article is its simple implementation and very good final result of scanned data if there is enough of subdivision. The disadvantage of mentioned method is necessary very much triangles in result object.

#### Acknowledgement

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