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3D Reconstruction and Animation of Brain MRI Images Based on Matlab

Hong Dai*

School of Computer and Information Engineering, Shanghai Second Polytechnic University, Shanghai, 201209, China

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ABSTRACT

The following algorithms are proposed and realized by MATLAB programming based on the brain MRI images: (1) The 3D surface of the brain is reconstructed using MC algorithm. (2) A rotate animation of the brain is created and displayed by 3D rotate transformation and animation functions of Matlab. Result shows that the algorithm can show the brain accurately and quickly, takes up less space in memory.

1. Introduction

Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) techniques have been widely used in disease diagnosis, but these imaging methods can only provide two-dimensional images of the human body. Recently, 3D visualization technology has become a research hotspot in medical image processing. This technique can extract the three-dimensional structural information of human tissue from the tomographic image sequence, which plays an important role in assisting diagnosis, surgical simulation and guiding treatment. MATLAB is a mathematical software produced by MathWorks, a powerful, for algorithm development and data analysis in almost all engineering fields, and easy to program, easy to learn and use.

This paper realizes the 3D reconstruction of the brain MRI image and generates the rotation animation, which can be applied to the computer-aided teaching system in the field of brain disease diagnosis and medicine.

2. 3D Reconstruction of Brain MRI Images

The Marching Cubes (MC) algorithm was used to draw the 3D reconstruction of the brain MRI images. The basic idea is [1]: The "equivalent surface" of each voxel is extracted from the information on the surface characteristics of the object, which constitutes the 3-dimensional surface of the object. The steps are as follows:

(1) Equivalent Extraction

The brain image sequences are sequential superimposed into a three-dimensional bulk dataset f (x, y, z), and

**Corresponding Author:*
Hong Dai,
School of Computer and Information Engineering, Shanghai Second Polytechnic University, Shanghai, 201209, China;
Email: daihong419@163.com

the "equivalent" actually means a surface in space where f (x, y, z) is equal to the threshold k [4]:

$$f(x, y, z)=k \tag{1}$$

where k is the threshold. The k takes the threshold when dividing the brain image, k =20. To produce a smooth surface, the dataset was smoothed with a Gaussian low-pass filter before extraction.

(2) Lighting Effect Settings

Light effects were set up using the phong model.

3. Brain Rotation Animation Display

In order to observe the brain structure from all directions, the reconstructed results can be transformed in 3D rotation and animated for display [5]. The basic idea is that the graph is rotated in three dimensions, and its structure does not deform because the isosurface connection mode is unchanged. The brain graph is rotated around its centroid and displayed as follows:

(1) Move the centroid of the graph to the origin. The homogeneous transformation matrix [2] is:

$$\boldsymbol{T}_1=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x_g & -y_g & -z_g & 1 \end{bmatrix} \tag{2}$$

among $\mathbf{x}_g=\frac{\sum_{i=1}^{n} x_i}{N}$, $y_g=\frac{\sum_{i=1}^{n} y_i}{N}$, $z_g=\frac{\sum_{i=1}^{n} z_i}{N}$, N--Total number of pixels in the dataset;

(x_i, y_i, z_i) - Coordinates of the pixel i in the dataset.

(2) Compared with the origin (i.e., the center of mass), the rotation transformation matrix is:

$$\boldsymbol{T}_2=\boldsymbol{R}_X\boldsymbol{R}_Y\boldsymbol{R}_Z \tag{3}$$

among $\mathbf{R}_X=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha & 0 \\ 0 & -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$,

$\mathrm{R}_Y=\begin{bmatrix} \cos\beta & 0 & -\sin\beta & 0 \\ 0 & 1 & 0 & 0 \\ \sin\beta & 0 & \cos\beta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$, $\mathrm{R}_Z=\begin{bmatrix} \cos r & \sin r & 0 & 0 \\ -\sin r & \cos r & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

α ,β, γ are the angles of the graph rotate around the X, Y and Z axes respectively.

(3) Move the centroid to the original position. The transformation matrix is:

$$\boldsymbol{T}_3=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ x_g & y_g & z_g & 1 \end{bmatrix} \tag{4}$$

Considering the above three steps, the transformation matrix of the brain graph rotating around its own center of mass is:

$$\boldsymbol{T}=\boldsymbol{T}_1 \bullet \boldsymbol{T}_2 \bullet \boldsymbol{T}_3 \tag{5}$$

Let any point on the drawing (x, y, z) rotate around the center of mass be (x_1, y_1, z_1), Then

$$[x_1, y_1, z_1, 1]=[x, y, z, 1] \bullet \boldsymbol{T} \tag{6}$$

(4) Animated Display and Storage

Set brain graphics from the original position, each time with its center of mass as the origin,

rotate △ α, △ β, △ γ around X, Y, Z axis respectively, and store the picture as a frame of the animation file, display the current graphics while erase the previous graphics, total rotate 360 degrees to produce animation effect [3], finally put all the images in the avi format animation file.

4. Matlab Program of This Method

Programming environment: Matlab2007. Experimental data source: matlab's own brain MRI image sequence: "MRI". 3D reconstruction and rotation animation display program of the brain is as follows(brainavi.m) :

```
% brainavi.m
clear        % clear memory
clc          %clear the screen
Figwin=figure ('position', [50 50 450 450], 'Name', 'Brain 3 D reconstruction and rotation animation demonstration', 'NumberTitle', 'off', 'Menubar', 'none');
% Generates a graphical window titled "Brain 3D reconstruction and rotation animation demonstration"
%%%1.Read-in brain MRI images%%%%
load mri          % Brain MRI image data are loaded into computer
D=squeeze (D);  % convert D from 4 to 3 dimensions
Ds=smooth3 (D); % uses a Gaussian low-pass filter to smooth D,create Ds
%%%2. 3D reconstruction with rotation animation of the brain%%%
fv=isosurface(Ds,20);
% Brain isosurface was extracted with threshold k=20, shown in formula (1).The fv is a structural array, where fv.vertices is the vertices is the vertex information for the graph; the fv.faces is the surface information for the graph.
fv2=isocaps (D, 5);    % Extraction of the upper brain cap, threshold k=5
yuan=fv.vertices;      % Make yuan is the vertex information of the original brain graph
yuan2=fv2.vertices;      % Make yuan2 is the vertex information of the original brain graph
N=length (yuan);      %N and N2 are the number of pixels
```


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of yuan and yuan2, respectively
N2=length(yuan2);
xg=sum(yuan(:,1))/N;
yg=sum(yuan(:,2))/N;
zg=sum(yuan(:,3))/N;
xg2=sum(yuan2(:,1))/N2;
yg2=sum(yuan2(:,2))/N2;
zg2=sum(yuan2(:,3))/N2;
% For the centroid of yuan and yuan2, see formula (2)
T1=[1 0 0 0;0 1 0 0;0 0 1 0;-xg -yg -zg 1];
T3=[1 0 0 0;0 1 0 0;0 0 1 0;xg yg zg 1];
T12=[1 0 0 0;0 1 0 0;0 0 1 0;-xg2 -yg2 -zg2 1];
T32=[1 0 0 0;0 1 0 0;0 0 1 0;xg2 yg2 zg2 1];
%3D T3 in T 3 rotation matrix, see Equations (2), (4)
M=24;     % Number of animated screen, M=24
mov=avifile('brainRotate.The avi');
% Create the brain rotation animation file 'brainRotate.
avi'
for j=1: M  % produces, displays, and saves brain rotation
animation
xian=0;
xian2=0;
% Initialization of x i a n and xian2.The Xian and xian2
are the animated images after each rotation of yuan and
yuan2, respectively.
th=2 * pi / M * j;   % Angle th for each rotation around the
Z axis.
A = 0;               % Angle A for each rotation around the
X-axis.
b=0;            % b for each rotation around the Y axis.
Rx=[1 0 0 0;0 cos(a) sin(a) 0;0 -sin(a) cos(a) 0;0 0 0 1];
Ry=[cos(b) 0 -sin(b) 0;0 1 0 0;sin(b) 0 cos(b) 0;0 0 0 1];
Rz=[cos(th) sin(th) 0 0;-sin(th) cos(th) 0 0;0 0 1 0;0 0 0
1];
T2=Rx * Ry * Rz;%3D rotation T2, see formula (3)
T=T1 * T2 * T3;
% Brain graphics and top cover transformation matrices
T and TT rotating around the own center of mass, see for-
mula (5)
TT=T12*T2*T32;
The xian= [yuan ones (N, 1)] * T;
% 3D rotation transformation of brain graphics and upper
cover, see formula (6)
xian2=[yuan2 ones(N2,1)]*T;
The xian=xian (:, 1:3);
% the brain rotates 360 degrees around its centroid in par-
allel to the z-axis (24 frames in total)
The xian2=xian2 (:, 1:3);
% brain cap rotates 360 degrees in the direction parallel to
the z axis (24 frames)
daspect([1,1,0.4]);view(3)
patch('Vertices',xian, 'Faces',fv.faces,'Facecolor',[1,0.75,
0.65],'EdgeColor','none');hold on;
patch('Vertices',xian2, 'Faces',fv2.faces,'FaceColor',[1,0.
75,0.65],'EdgeColor','none');hold on;
% 3D reconstruction of the brain and its upper cover.The
vertex is the xian and xian2 that have passed the 3D rota-
tion, while the surface information is still the fv.The faces
with fv2.faces, and set the graphic surface color with the
edge color.
lightangle (th, 30); lighting phong;  % lighting with phone
model
xlabel ('x'); ylabel ('y'); zlabel ('z');  % displays the X, Y,
and Z axes
F=getframe;                  % produces a frame of animation
mov=addframe (mov, F);         % Add the animation frame
F to the animation file mov
name=strcat('a',num2str(j));
print('-dtiff',name);
% Save each frame of the animation with the name aj.In
the image file for the tif (j=1~24)
   if j~=M + 1                 % will erase the image from the
previous frame
   delete(gca);
   end
   end
aviobj1=close (mov);             % Display is finished, close
the animation file
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
```

5. Graph of the Experimental Results

Display the brain MRI image sequence "MRI" (27 images in total) brought by the matlab by using the above procedure, where the rotation parameters are set in Table 1:

Table 1. Rotation parameter setting for the brain animation

The frame number of the animation	Total rotation Angle	Δα	Δβ	Δγ
24	360°	0°	0°	15°

The 3D reconstruction results of the MC algorithm are shown in Figure 1, and the frames of the rotation animation are shown in Figure 2(a) ~ (e).

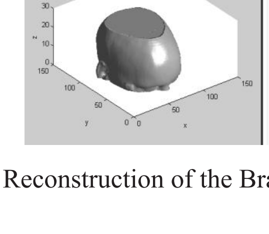
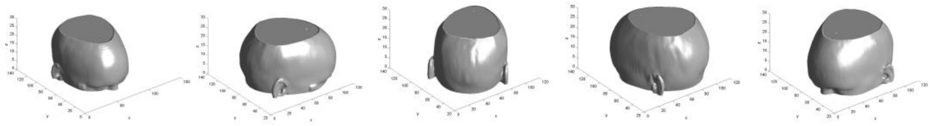


Figure 1. 3D Reconstruction of the Brain MRI Images



(a) (b) (c) (d) (e)

Figure 2. Frames 1, 5, 10, 15, 20 of the Brain Rotation Animation

The total time for brain 3D reconstruction, animation and generation, display and preservation by using the above algorithm is 19.75 s, and the animation file size is 126 k bytes.

6. Conclusions

This paper proposes a 3D reconstruction and animation display algorithm, which is implemented by matlab software programming. The experimental results show that the method can display the brain comprehensively, and run quickly and occupy small memory space. Using this algorithm and image segmentation technology allows 3D visualization of all tissues of organs in human body.

References

[1] Tian, J., Zhao, M.Ch., He, H.G., 2004. Theory and Practice. Beijing: Tsinghua University Press.

[2] Cheng, S.Y., Zhang, Q.Zh., 2003. Computer Graphs. Beijing: Metallurgical Industry Press.

[3] Dai, H., 2007. Image segmentation and information extraction of CT sequence. Journal of the University of Shanghai for Science and Technology. 29(2), 165-169.

[4] Dai, H., Yang, Y.F., 2010. Algorithm based on fast image segmentation and animation generation of Matlab talus. China Organizational Engineering Research and Clinical Rehabilitation. 26(4), 4764-4769.

[5] Zhou, Zh.H., Wu, Y.Zh., Zhao, M., 2010. Medical Image Programming technology. Beijing: Electronic Industry Press.

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