Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 05, pp.50280-50283, May, 2017

INTERNATIONAL JOURNAL
OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

FORENSIC FACIAL RECONSTRUCTION USING MARCHING CUBES

*Tabassum Khan, Apurva Sonavane, Sannan Momin and Prof. Mansing Rathod

K.J. Somaiya Institute of Engineering and Information Technology, Sion

ARTICLE INFO

Article History:
Received 19th February, 2017
Received in revised form
17th March, 2017
Accepted 20th April, 2017
Published online 23rd May, 2017

Key words:

Generating 3d Face, Volume Rendering, Marching Cubes, Mesh Generation, Forensic Facial Reconstruction.

ABSTRACT

The identity of a person is of critical importance in Forensic department and in some cases, the facial reconstruction becomes a critical stage when the face is unrecognizable. Forensic facial reconstruction is the reproduction of the unknown face based upon the soft tissues that overlays the bony structure. In this paper, we plan to propose a methodology that can be carried out to automate the facial reconstruction from skeletal remains. A dataset of CT head scans is used to produce a segmented model and an iso-surface is generated with the help of Marching Cubes algorithm. The algorithm is based on the concept of 3d voxels present in the DICOM images and extracts the iso-surface from the images through linear interpolation. The implementation is carried out in MATLAB which provides an easier interface to deal with images. Variousdatabase was tested with Marching Cubes algorithm as well as with in-built MATLAB function called isosurface and the study shows that Marching Cubes is a better and a faster approach to facial reconstruction.

Copyright©2017, Tabassum Khan et al. *This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.*

Citation: Tabassum Khan, Apurva Sonavane, Sannan Momin and Prof. Mansing Rathod, 2017. "Forensic facial reconstruction using marching cubes", *International Journal of Current Research*, 9, (05), 50280-50284.

INTRODUCTION

The subject of forensic facial restoration is concerned with the reproduction of the facial features of an individual for the purposes of recognition and identification. At a more scientific level, it is concerned with examining and measuring the thickness and form of the soft tissues to understand how these tissues are spatially related to the underlying skull. There are various methods and traditional plastic method is one of them where they use clay model to design the facial structure. The artists carrying out this model construction rely on tissue depth tables, which is mainly based on intuitions. This procedure has many disadvantages, an important one amongst which is, that it is an artistic method meaning that the process is subjective. Current computer based reconstruction techniques build the final reconstruction starting from a reference facial model. Because a standard method for creating three-dimensional forensic facial reconstructions has not been widely agreed upon, multiple methods and techniques are used.In this study, we use Marching Cubes algorithm to construct the facial tissue from a set of CT scan slices. Marching Cubes algorithm is used to extract the iso-surface of same density by creating polygon surfaces from the DICOM images. With the help of this algorithm, a 3d model of the bone surface as well as the facial tissue is generated from a stack of 2d slices. The implementation is carried out in MATLAB which is a lot easier and a faster procedure compared to C++ and Open GL.

Corresponding author:* **Tabassum Khan,
K.J. Somaiya Institute of Engineering and Information Technology, Sion

Marching Cubes Algorithm

Marching Cubesby Lorensen and Cline, is the most popular algorithm for creating a polygonal surface representation of an isosurface of a 3D scalar field. This is explained in paper (William E. Lorensen and Harvey E. Cline, 1987) and how it is a faster and a better approach than any other algorithms present. Combined with lookup tables, linear interoperability and divide and conquer approach, it gives topologically correct triangular approximation of the iso-surface for any cube configuration.

Algorithm Details

Marching Cubes is an algorithm for rendering isosurfaces in volumetric data by using 3d values (voxel) in an image. The voxel defined by the pixels at the 8 corners of the cubes determine how the surface is going to be cut. By user-specified isovalue (RGB value), the voxels are determined if they have a value greater than or less than the isovalue, that is, whether the voxels are inside or outside the threshold value. By determining this, we can calculate which edges intersect the isosurface and can create a set of triangulated patches. By connecting the patches from all cubes, we can create a 3D polygon surface which is a close approximation of the original surface.

There are two major principles of this algorithm:

1. First, the triangle patches are created according to the isovalue defined by the user, and

2. The normals at each vertex of every triangle are calculated.

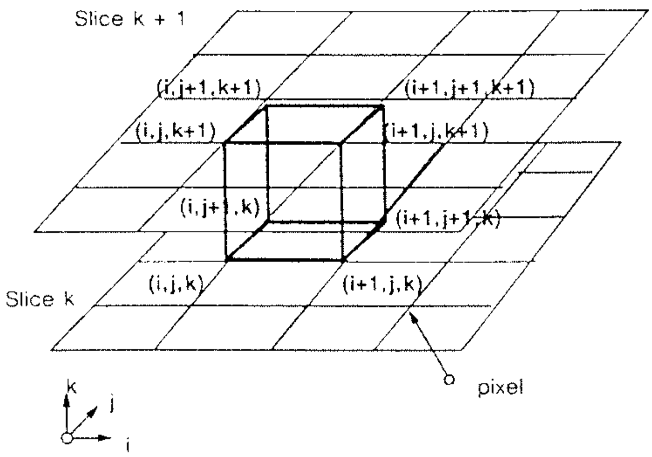

Fig.1. The Marching Cubes and its 8 vertices

The marching cubes uses a *divide and conquer* approach as described earlier and the logical cube is created by the 8 pixels defined by 4 vertices, each from 2 adjacent slices. When the value of the vertex is greater or equal to the isovalue, then it is inside the surface, but when it is less than the isovalue, it is considered outside the surface.

Creating Triangulated Surface

There are 256 possible configurations based on the 8 vertices and 2 states, 2^8, that a surface can intersect the cube based on the isosurface value which divides the cube into 2 parts. Out of these, 2 cases are trivial, where either all the vertices are inside or outside the cubes; thus, no intersection of the surface and cube takes place. According to Lorensen and Cline approach, the 256 possibilities is reduced to only 14 patterns which is much easier to implement and less error prone. Also, there are many algorithms that have improved the Marching Cubes algorithm proposed by Lorensen and Cline. When one vertex is inside the surface and the other is outside the surface, edge intersection occurs, where the cube edge cuts the surface and a triangle patch is formed. These triangular patches are generated with the help of the help of lookup table which contains the table of the edges intersecting with the surface for all the 14 cases.

Now, the process of generating surface patches can be applied to all the database, as in, the entire volume. This volume is formed by stacking all the slices one after the other and working with 2 adjacent slices at a time. Each cube can either be treated independently, or can be propagated through edge intersections between cubes. This increases storage and complexity a bit, but saves a lot of computation time.

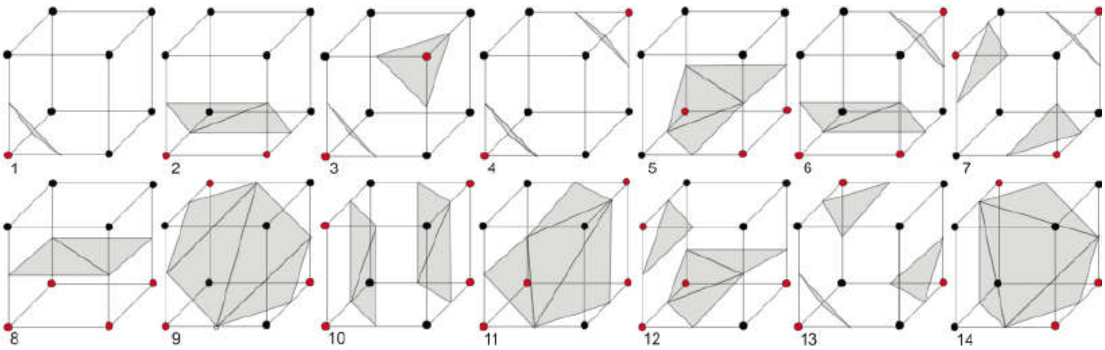

Fig.2. 14 Combinations of Triangulated Cubes

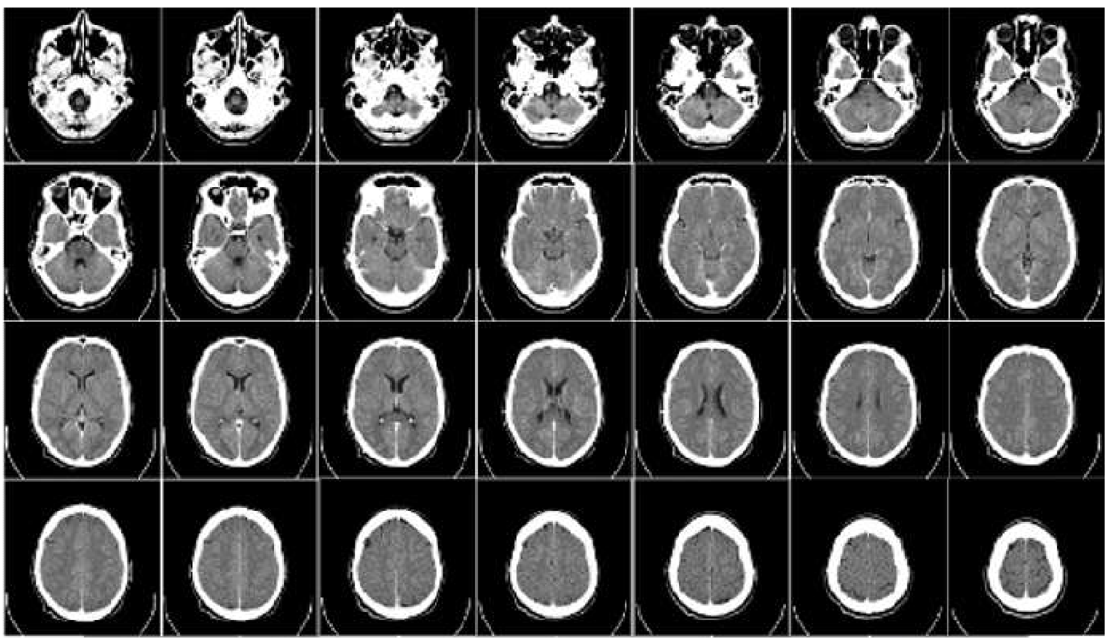

Fig.3. CT scan slices

Determining Normals

- The normal is calculated at each vertex to create a smooth rendering volume. The normal is calculated at each cube vertex using Central differences and then, interpolate the normal at each vertex of the cube.
- The output is in the form of triangle vertices and normal vertices that creates the 3d model of the 2d surface.

Implementation

The implementation was carried out in MATLAB due to its easy interface to carry out processes on imageswhich proved to be better than OpenGL and C++ combination of volume rendering. The inbuilt MATLAB functions are designed for easy manipulations and operations on images.

Pre-Processing DICOM Images

The database included 99 CT head scan slices from Stanford library. And various other databases from different sources were also tested by the program for computations and analysis. The database included in our study was already preprocessed, that is, the thickness and the dimensions of the image were made similar. If the database is not analogous, then care should be taken to made the dimensions and thickness equal. Each CT slice is a 512 x 512 matrix stored in the database ranging from -1500 to 3000 and the units are called Hounsfield Units (HU). Each slice had a consistent slice thickness ranging from 1mm to 5mm and pixel spacing ranging from 0.5mm x 0.5mm. These values create 3D pixels called voxels in the DICOM images. The smaller the slice thickness and pixel spacing, the clearer the imageand the more accurate tissue measurements. The CT scan slices can be seen in Figure 3.

C. Creating a stack of the CT scan slices

A stack of all the CT scan slices is created by the MATLAB functions and they are placed one after the other. MATLAB stores the value of each pixel of the slices in the matrix. 99 CT scan slices of 512x512 dimensions are stored in a 512x512x99 matrix, stacked one upon other with the help of strcat() function. The marching cubes works with these pixel values that is stored in the matrix. The marching cubes through the adjacent slices and checks for all the pixel values, if they are higher than the isovalue, then they are assumed 1 and if the pixel value is lower, then it is 0.

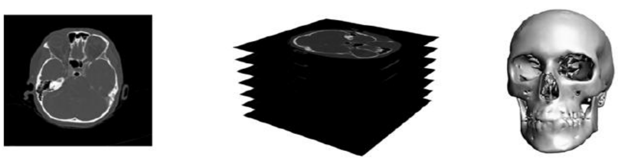

Fig. 4. (from left) CT scan – 2D slices, DICOM images, 3D generated model

Applying Marching Cubes on the stack of slices

Marching Cubes generate a 3D mesh surface at an isosurafce value of a 3D volumetric data. In the study, the marching cube function can be called by a single command:

(F,V) = MarchingCubes(x,y,z,c,iso).

The x, y, z are the matrices that represent the coordinate axes. The co-ordinate matrices can be created using MATLAB's meshgrid command:

(x,y,z)=meshgrid(xmin:xdelta:xmax,ymin:ydelta:ymax,zmin:zdelta:zmax).

C is the 512x512x99 matrix that stores all the pixel values (grayscale) of the database. X, Y and Z are the co-ordinate matrices that are of same size as c, which is the 3D matrix of image intensity values. The iso is the isovalue, that is user specified and cannot be defined universally. It totally depends on what the user wants to achieve from the segmentation. For example, the isovalue for bone surface is different and for tissue surface, it is different.

The tissue surface construction and the bone surface construction is shown in Figure 5.

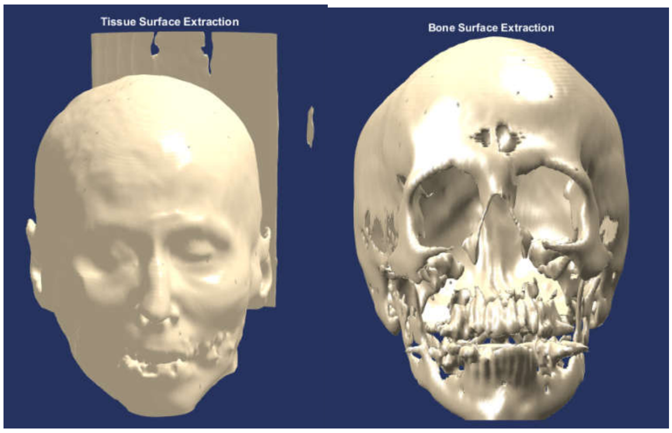

Fig. 5. (from left) Tissue Surface Extraction at isovalue = 55, Bone surface extraction at isovalue = 15

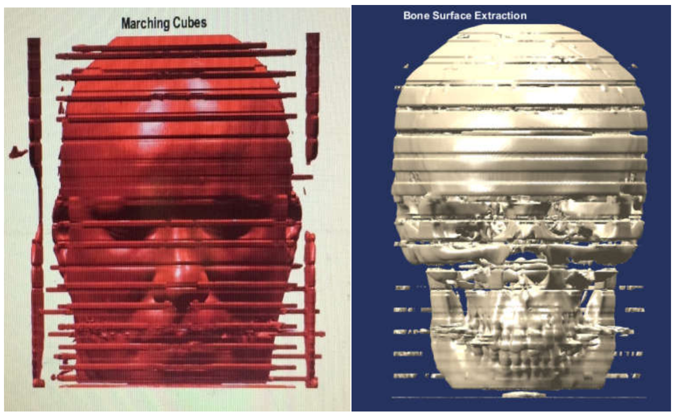

Fig. 5. (from left) Tissue surface extraction at isovalue = 255, Bone surface extraction at isovalue = 1500

Experiments and Results

Various databases were tested for this experiment and was found that Marching Cubes performed better and faster than the MATLAB isosurface function. MATLAB deals with images as matrices which makes it a lot easier to perform operations on them. The pixel values are stored in the form of matrices and each pixel is manipulated or at least checked during a process. Dealing images with pixel is what make

MATLAB a much easier and faster platform to work o images than any other. Marching cubes algorithm gave better and accurate results in all the test cases. The output shown in Figure 5 took almost half an hour to get implemented with isosurface function, whereas with Marching Cubes algorithm it took not more than 5 mins. Although, in some cases, standard Marching cubes algorithm proved to be inefficient. The traditional marching cubes generated holes and duplicate vertices due to which the output formed did not seem so accurate. To deal with such issues, a program for holes and duplicate vertices was included in the algorithm, which gave more accurate results. In one case as shown above in figure 6, the output was not smooth and this were dealt by inserting the average of 2 adjacent slices in between.

Conclusion

Marching Cubes Algorithm proposed by Lorenson and Cline was implemented to generate an approximate facial structure from CT scans. The proposed methodology outputs only the tissue surface, layered on the bone structure. This was successfully generated in MATLAB which provides a lot of easier interface to work withimages. The accuracy of the present methodology can be improved by working on the ambiguous cases of marching cubes. Also, this can be further worked upon by placing landmarks on the facial tissues and by using deformation methods. This can be done by creating a constrained face spaceusing PCA techniqueas mentioned in the paper (Blanz and Vetter, 1999). The facial features can then be placed on the model as explained in the paper (Peter Tu *et al.*). Thus, we have successfully implemented Marching Cubes in MATLAB to generate a 3D approximation model of the CT scan slices. We worked on removing duplicate vertices and holes produced in the traditional Marching Cubes to increase accuracy. The performance of this method was compared with an inbuilt MATLAB function isosurface. The results showed an improvement in overall performance and accuracy when Marching Cubes algorithm was used.

Acknowledgements

We would like to thank for theencouragementfrom our Principal, Dr. Suresh Ukarande, Head of the IT department, Prof. Uday Rote, Project coordinator, Prof. Harsh Bhor, and all other staff and people who have guided and supported us. Lastly, we would like to express our gratitude towards our guide, Prof. Mansing Rathod, for supporting us thoroughly and for being a strong source of guidance.

REFERENCES

A computer application for 3d craniofacial reconstructionand automatic skull-photo identification International Journal of Computer Science and Applications Techno mathematics Research Foundation

A morphable model for the synthesis of 3D FACES V. Blanz and T. Vetter. In Computer Graphics Proceeding, AnnualConference Series, pages 187 – 194, New York, 1999. ACM.

Automatic face recognition from skeletal remains Peter Tu; Rebecca Book; Xiaoming Liu; Nils Krahnstoever; Carl Adrian; Phil Williams 2007 IEEE Conference on Computer Vision and Pattern Recognition Year: 2007

Face reconstructions using flesh deformation modes Peter Tu, Richard I. Hartley1, William E. Lorensen, Majeid Allyassin1, Rajiv Gupta, Linda Heier, GE Corporate R&D Center 1 Research Circle, Niskayuna, N.Y. 12309, 2 Weill Medical College, Cornell University

Facial muscle anatomy based approach for forensic facial reconstruction in sri lanka Roshan N. Rajapakse; Anuradha K. Madugalla; Ishari. U. Amarasinghe; Vinavi H. Padmathilake; Anuja T. Dharmaratne; Damitha Sandaruwan; Muditha Vidanapathirana Advances in ICT for Emerging Regions (ICTer), 2012 International Conference on 2012

Improving facial reproduction using empirical modeling Graduate Research Assistant: Brian Wood, J. Wesley Hines (Principal Investigator), Dr. Chester Ramsey, Dr. Lee Meadows Jantz , Dr. Richard L. Jantz , Ms. Joanna Hughes The University of Tennessee

Marching cubes: A high resolution 3d surface construction algorithm William E. Lorensen; Harvey E. Cline; General Electric Company Corporate Research and DevelopmentSchenectady, New York 12301Date: Number 4, July 1987 '

Statistically deformable face models for cranio-facial reconstruction P. Claes; D. Vandermeulen; P. Suetens; S. De Greef; G. Willems ISPA 2005. Proceedings of the 4th International Symposium on Image and Signal Processing and Analysis, 2005.

Tissue map based craniofacial reconstruction and facial deformation using rbf network Yuru Pei; Hongbin Zha; Zhongbiao Yuan Image and Graphics (ICIG'04), Third International Conference on Year: 2004

****