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DEVELOPMENT OF 3D MODEL WITH ISO SURFACE RECONSTRUCTION ALGORITHM IN COSMETIC SURGICAL APLICATIONS

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ABSTRACT

The objective of this paper is to develop semi-automatic guided software for performing cosmetic surgery and fabrication of head phantom by the process of simulating three dimensional (3D) visualization techniques for improving therapeutic treatment with computer vision and innovative technologies. The 3D operation planning is one of the main applications in reconstructive and crania-facial surgeries. The current trend in surgical planning is with respect to tissue changes based on frontal analysis of 2D information sources such as photographs, X-rays, and CT/MRI etc. The proposed slicing technique will be suitable for the display of complex structures of the facial skeleton and can also be used to develop skull by 3D printing technology. The proposed method helps in developing of 3D reconstruction method with an aid of computer software for developing a 3D model from 2D CT/MRI scan with cross sections of a patient. A basic 3D model of outer face is created using algorithm of icon-surface reconstruction which defines proper icon-value or intensity value. This method can be used to construct different regions based on user defined value. Each region is reconstructed in 3D using different colours for identification. The development of 3D model based iso-surface extraction and reconstruction will provide better surgical results with fewer procedures, and also improve the functionalities to a greater extent.

Index Terms— Rapid prototyping, surface reconstruction, 3D volume, skull

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I. INTRODUCTION

3D visualization techniques suitable for the display of complex structures of the facial skeleton and of the skull base from a given set of CT images can be developed. Computer-based surgical planning has been investigated by many researchers over the past decade. The promise of the technology is to provide better surgical results with fewer procedures, decreased time in the operating room, lower risk to the patient (increased precision of technique, decreased infection risk), and a lower resulting cost. Because of their wide-ranging surgical impact, craniofacial operations require careful preoperative planning. The goal is to improve the functionalities to a considerable extent and there by reconstructing an aesthetically pleasing face for the patient. The desire to obtain these goals has led to a large number of research papers and clinical applications in this area. Routine use of surgical planning is still in its infancy, although the application of computer -based crania-facial measurement and surgical planning is clearly of great interest to surgeons. In this paper by using surface reconstruction algorithm a proper and near to perfect 3D model of a crania facial anatomy is proposed with an interactive surgical simulation system

The interactive surgical system can be used for the simulation of surgical alignments and re-alignments of bone and soft tissues to get the post-operative appearance of a patient's face before the cosmetic surgery. This focus of work should be in the first step of developing a 3D volume/model of face from the 2D CT/MRI images of human head. Two neighboring slices will form a vowel. The information from each slice is taken and it is processed to form the whole data of the volume created. The overall model reconstructs a 3D Model from 2D slices.

Medical image has its own uniqueness such as human tissues' wiggle and disturbance of power level in imaging equipment. These unavoidable factors add some noise into image data. Adding a filter module before reconstruction module to reduce the noise can improve the precision of the 3D images. A vowel is created from two adjacent cross-sectional 2D images opposite each other by selecting 8 pixels. An icon surface of the data field given is calculated using surface modeling. Three dimensional visualization techniques suitable for the display of complex structures of the facial skeleton and of the skull base from a given set of CT images can be developed for interactive surgical simulations before performing the actual surgeries. The produced 3D model can be used for educational purposes for the studying the craniofacial anatomy of the head and face.

3D models are widely used anywhere in 3D graphics. Actually, their use predates the widespread use of 3D graphics on personal computers. Many computer games used pre-rendered images of 3D models as sprites before computers could render them in real-time.

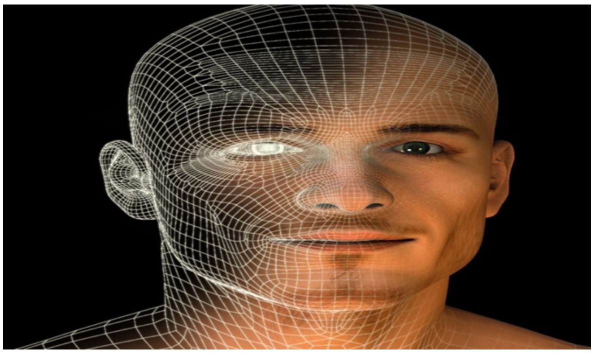

Fig.1.An Example of 3D modeling

Today, 3D models are used in a wide variety of fields. The medical industry uses detailed models of organs. The movie industry uses them as characters and objects for animated and real-life motion pictures. The video game industry uses them as assets for computer and video games. The science sector uses them as highly detailed models of chemical compounds.

The architecture industry uses them to demonstrate proposed buildings and landscapes through software architectural models. The engineering community uses them as designs of new devices, vehicles and structures as well as a host of other uses. In recent decades the earth science community has started to construct 3D geological models as a standard practice.

II. LITERATURE SURVEY

A. EXISTING METHODS

There are lots of prior works has been done on 3D reconstruction of face for bio-medical applications and purposes. Some limitations of these are high cost of implementation, for the process of generating the 3D reconstruction, dataset is not trivial, reconstruction of the facial surgery that cause the infection, Intensive computation, less speed, high cost, low quality reconstructed image.

B. PROPOSED METHOD

Surface reconstruction is the process by which extraction of surfaces is done from a 3D array having same density in 3D volume. A basic 3D model of outer face is created using algorithm of icon-surface reconstruction by defining proper icon-value or intensity value. The proposed method can be used to construct different regions based on user defined value. Each region is reconstructed in 3D using different colors for identification. To develop an automatic guided software for performing cosmetic surgery by the process of simulating three dimensional visualization techniques. 3-D reconstruction of images is an attractive field generally in digital image processing techniques especially in bio-medical applications using of cranial anatomy. Developing a 3D model with CT/MRI images based on iso-surface extraction and reconstruction provides better surgical results with fewer procedures, and improve the functionalities to a considerable extent. This includes skin soft tissues, hard tissues and extra hard bones like jaws and teeth.

The developed 3D Model for different layer of human face model of face with highlighted the affected region, the affected part only and the model of complete face after chopping the selected portion. A 3D reconstruction method is used for developing a 3D model from 2D CT/MRI scan of axial slides of a patient. The given set of slices is then processed to extract the internal layers and structures of head based on interested density of 3D volume depend on two dimensional pixel intensity. 3D modeling is then extended to ROI (region of interest) approach. The ROI based reconstruction can develop cross-section of faces, part of skin,/soft tissues and internal structures in 3D view. The images given are square images of size 512X512, which should be resized to a size of 50X50 to reduce the execution time and RAM usage of the program. The images taken will then batch processed to form a 3Dl array with selected number of images. A basic 3D model of outer face is created using algorithm of icon-surface reconstruction by defining proper icon-value or intensity value. The 3D modeling of facial structures can be divided into three important parts as follows:

(i) Basic 3D model of human face and head.
(ii)Extract different inner surfaces of head in three dimensional views.
(iii)Developing 3D parts based on focus of ROI (Region of Interest).

C. 3D VISUALISATION BASED ON ROI (REGION OF INTEREST)

ROI is the process of developing a particular region based on surgeon's interest. If surgeon wants to focus and concentrate anywhere after noticing anything extra ordinary like an infection or defect, he can select that particular portion using mouse from the image. The algorithm is restructured with change of icon value as per user requirement is done for extracting different surfaces and reconstruction of inner layers inside the head.

The 3D model created by ROI can then be extended in developing various levels of internal structures with highlighting the portion selected specifically the extracted cross sections. At any time the 3D model can be cut apart for viewing the internal structure and cross sections. The selection of ROI can make 3D modeling limited to specific number of slides where the surgeon wants to focus and view the region in 3D. The dataset will be a collection of 250-400 CT/MRI images which have been taken after scanning a person's head from top to bottom. These images will be in a form of raw medical data which will have noises in it and also the relevant details wouldn't be segmented out from the unimportant background. The sample data set images used for the proposed work are shown in Fig.2.

Fig.2. Data set CT/MRI

Pak. J. Biotechnol. Vol. 13 (special issue on Innovations in information Embedded and Communication Systems) Pp. 193- 198 (2016)

III. ISO SURFACE RECONSTRUCTION ALGORITHM

A voxel is created from two adjacent cross-sectional 2D images opposite each other by selecting 8 pixels. They are at the vertices of a cube, and their coordinates are

(i, j, k), (i, j+1, k), (i+1, j, k), (i+1, j+1, k), (i, j, k+1),
(i, j +1, k +1), (i+1, j, k +1) and (i+1, j +1, k +1).

An iso surface of the data field given is calculated using surface modeling. The predefined 8 vertices are used to determine the whether the voxel is inside/outside the iso surface.

The rule to classify the vertices is by,

(i) If (value of a vertices is not less than the value of the iso surface)
{The vertices is outside the iso surface}. Else
if (value of the vertices is less than the value of
the iso surface)
{The vertices is inside the iso surface}

(ii)Find border pixels which have vertices both inside and outside the voxel.

(iii)Calculate the coordinates of the intersection points by use of linear interpolation.

In two and three dimensions, the range measurements correspond to curves or surfaces with weight functions, and the signed distance ramps have directions that are consistent with the primary directions of sensor uncertainty. Fig.3 illustrates the two-dimensional case for a range curve derived from a single scan containing a row of range samples.

In practice, we use a fixed point representation for the signed distance function, which bounds the values to lie between D_{min} and D_{max} as shown in the Fig.3. The values of D_{min} and D_{max} must be negative and positive, respectively, as they are on opposite sides of a signed distance zero-crossing. For three dimensions, The whole algorithm is summarized as shown below. First, all voxel weights are set to zero, so that new data will overwrite the initial grid values.

A. PSEUDO CODE FOR VOLUMETRIC INTEGRATION

```
/* Initialization */
For each voxel
{Set weight = 0}
/* Merging range images */
For each range image {
/* Prepare range image */
Tesselate range image
Compute vertex weights
/* Update voxels */
For each voxel near the range surface
 {Find point on range surface
Compute signed distance to point
Interpolate weight from neighboring vertices
Update the voxel's signed distance and weight}
/* Surface extraction */
Extract an iso surface at the zero crossing.
```

Next, each range image by constructing triangles from nearest neighbors on the sampled lattice. We avoid tessellating over step discontinuities (cliffs in the range map) by discarding triangles with edge lengths that exceed a threshold. We must also compute a weight at each vertex

Once a range image has been converted to a triangle mesh with a weight at each vertex, the voxel grid can be updated. The signed distance contribution is computed by casting a ray from the sensor through each voxel near the range surface and then intersecting it with the triangle mesh, as shown in Fig.3. The weight is computed by linearly interpolating the weights stored at the intersection triangle's vertices. After determining the signed distance and weights, the update formula can be applied.

At any point during the merging of the range images, the zero-crossing iso surface can be extracted from the volumetric grid. Iso surface extraction algorithms have been well explored, and a number of approaches have been demonstrated to produce tessellations without consistency artifacts. These algorithms typically decompose the volume into cubes or tetra hedra with sample values stored at the vertices, followed by interpolation of these samples to estimate locations of zero-crossings.

IV. SYSTEM OVERVIEW

The ROI based reconstruction can develop a cross-section of face, part of skin,/soft tissues and internal structures in 3D view. The images given are square images of size 512x512, which should be resized to a size of 50x50 to reduce the execution time and RAM usage of the program.

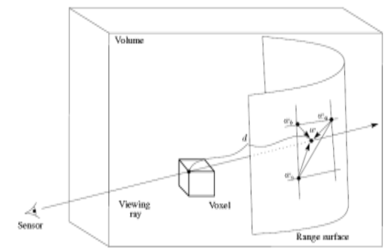

Fig.3. Range surface sampling to update the volume. The weight w and signed distance d computed to update the voxel by casting a ray from sensor through the voxel on to the range surface by linearly interpolating the weights stored at neighbouring range vertices.

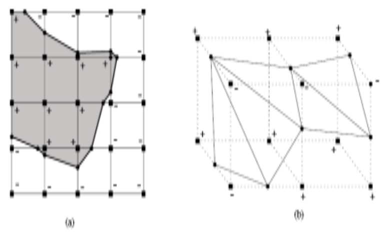

Fig.4. Discrete iso surface extractions in two dimensions a typical iso contour extraction algorithm interpolates grid values to estimate iso value crossings along lattice lines by connecting the crossings with line segments in three dimensions the crossings are connected with triangles.

The images taken will then batch processed to form a 3D array with selected number of images. The surgeon has the provision of viewing and analyzing all the slices given using a slider control. The screen layout is shown in Fig.5.

The 3D modeling of facial structures can be divided into three important parts as follows:
(i) Basic 3D model of human face and head.
(ii)Extract different inner surfaces of head in three dimensional views.
(iii)Developing 3D parts based on focus of ROI.

Data vectors are first extended to a continuous vector field on a bounding volume, which is then integrated in the least squares sense yielding an implicit function whose zero level set approximates the data points. Function discretizations associated with regular grids automatically produce iso surface polygon meshes. Extrapolating missing and noisy data, integrating multiple scans, developing data structures and algorithms optimized for fast visualization and geometry processing, are challenging problems.

The plan to use multi-resolution data structures to integrate streams of point clouds in real time. Implicit representations have the advantage of dealing with arbitrary topology introduces an adaptive hierarchal implicit representation composed of local quadric patches and weights associated with nodes in a oct-tree. Given that for rendering or post-processing we extract an iso surface over a regular grid (e.g., via Marching Cubes), it is worth exploring reconstruction algorithms that use implicit functions defined as a regular scalar field. In the area of geometry processing, the notion of decoupling the filtering of normal fields and geometry has emerged as a powerful method for denoising. This volumetric method for surface reconstruction directly incorporates both point and normal information. Instead of imposing constraints and regularization directly on the values of the potential (scalar) field, we impose constraints and regularization on the gradient field. This can be implemented using a combination of least-squares fitting and solving a Poisson problem over a uniform grid. The general problem of implicit surface reconstruction is as follows.

Given an oriented point cloud i.e., p points and their normal's,
$D = \{(\mathbf{pi},\mathbf{ni})\}$ sampled from a surface M, compute an implicit surface
$M' = \{\mathbf{p} | f(\mathbf{p}) = 0\}$ where f: R3 →R and
$\forall(\mathbf{pi},\mathbf{ni}) \in D$ Ñ$f(\mathbf{pi}) = \mathbf{ni}$ and $f(\mathbf{pi}) = 0$.

The reconstruction of oncologic defects remains a critical element in the surgical treatment of head and neck cancer. Goals of reconstruction are wound healing, vital structure protection, function, and cosmetic. In this the reconstructive ladder as it applies to defects of the oral cavity, or pharynx, nose, orbit, midrace, hypo pharynx, larynx, and cervical esophagus. New approaches in surgical reconstruction are discussed, including salvage surgery after failed chemo radiotherapy, the use of perforator flaps, and the frontier of transpolar laser microsurgery defects that require flap reconstruction.

This shows that surface reconstruction from oriented points can be cast as a spatial poisson problem. The poisson formulation considers all the points at once, without resorting to heuristic spatial partitioning or blending, and is therefore highly resilient to data noise. Unlike radial basis function schemes, our poisson approach allows a hierarchy of locally supported basis functions, and therefore the solution reduces to a well conditioned sparse linear system. We describe a spatially adaptive multi scale algorithm whose time and space complexities are proportional to the size of the reconstructed model. Experimenting with publicly available scan data, we demonstrate reconstruction of surfaces with greater detail than previously achievable.

Reconstructing 3D surfaces from point samples is a well studied problem in computer graphics. It allows fitting of scanned data, filling of surface holes, and re meshing of existing models. We provide a novel approach that expresses surface reconstruction as the solution to a Poisson equation. Like much previous work (Section 2), we approach the problem of surface reconstruction using an implicit function framework. Specifically, like this compute a 3D indicator function χ (defined as 1 at points inside the model, and 0 at points outside), and then obtain the reconstructed surface by extracting an appropriate iso surface.

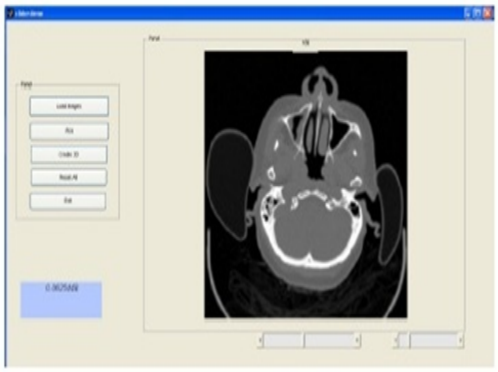

Fig.5. Image Viewer developed for the surgeon

The key insight is that there is an integral relationship between oriented points sampled from the surface of a model and the indicator function of the model. Specifically, the gradient of the indicator function is a vector field that is zero almost everywhere (since the indicator function is constant almost everywhere), except at points near the surface, where it is equal to the inward surface normal. Thus, the oriented point samples can be viewed as samples of the gradient of the model's indicator function.

B. INTERACTIVE SURGICAL SIMULATION SYSTEM

The interactive surgical simulation system is proposed. It can be used for the simulation of surgical alignments and re-alignments of bone and soft tissues to get the post operative appearance of a patient's face before the cosmetic surgery. The focus of work should be in the first step, of developing a 3D volume/model of face from the 2D CT/MRI images of human head.

3D Reconstruction by iso surface reconstruction is the process by which extraction of surfaces from a 3D array having same density. In collection of images the density value or iso value used for extraction will be the intensity specified for images. The intensity or iso -

value for extraction will vary from (1-255) range with '0' representing a void or empty space in 3D. The developed 3D model for the input slices is shown in Fig.6.

The 3D model created by ROI can then be extended in developing various levels of internal structures with highlighting the portion selected specifically. The extracted cross sections are shown in Fig.8. At any time the 3D model can be cut apart for viewing the internal structure its cross sections pre-processing by filtering medical image has its own uniqueness such as human tissues' wiggle and disturbance of power level in imaging equipment.

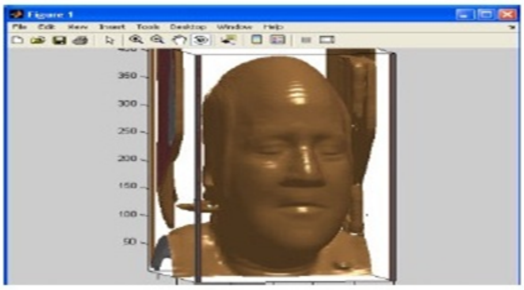

Fig.6. outer 3D model of Created face

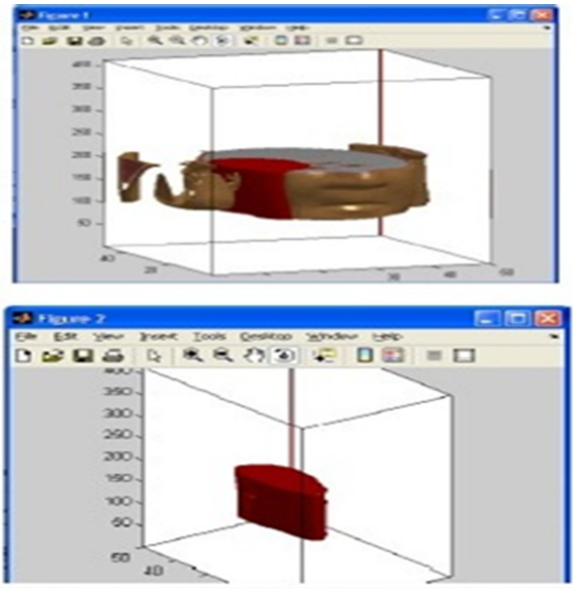

Fig.7. Selection of ROI from slice and extraction of ROI

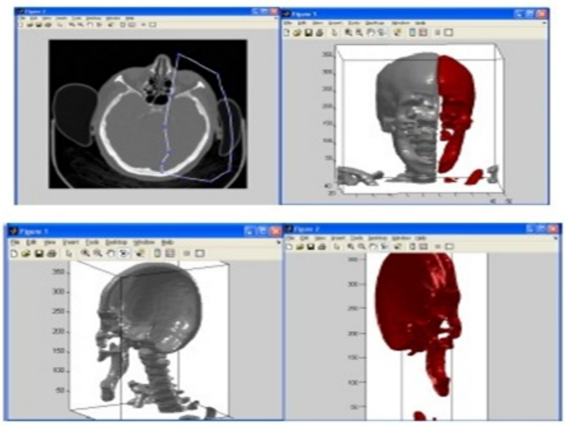

Fig.8.View of cross sections in 3D view based on region of interest

The unavoidable factors add some noise into image data. By using filter module before reconstruction the noise can be reduced and improves the precision of the 3D images.

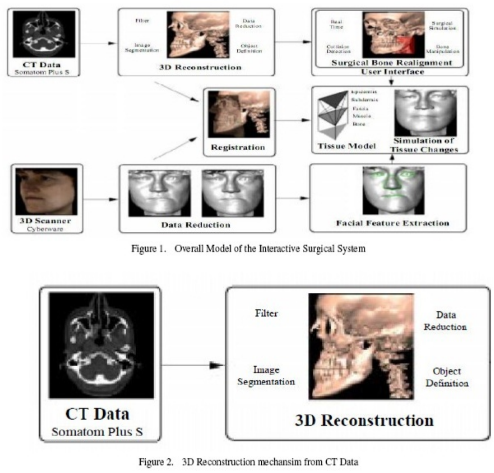

Fig.9. 3D reconstructions of CT data

V. Conclusion and Future work

A basic 3D model of a patient's face is developed from a data set of 2D CT scan of head using algorithm of icon-surface reconstruction. Internal structures of a human head are extracted and developed in 3D view from skin to hard tissues layer by layer using the proposed method by defining the icon-value. Three dimensional models of different parts of head are developed giving importance to ROI. The 3D models of whole face with region selected and remaining portion after its removal are developed separately with region of interest highlighted as per surgeon's interest. The 3D Reconstruction based on ROI is used to extract a portion suspected to be infected by the surgeon in 3D view from a given number of 2D slices.

The 3D view will show the different inner layers in head affected by the infection. The ROI approach can be used to extract a particular cross section of head. The ROI based 3D modeling is further extended to extract different layers inside the cross sections of head.

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