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Web based 3-D Medical Image Visualization System on the PC

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Abstract

*With the recent advance of Web and its associated technologies, information sharing on distribute computing environments has gained a great amount of attention from many researchers in many application areas, such as medicine, engineering, and business. One basic requirement of distributed medical consultation systems is that geographically dispersed, disparate participants are allowed to exchange information readily with each other. Such software also needs to be supported on a broad range of computer platforms to increase the software's accessibility. In this paper, the development of world-wide-web based medical consultation system for radiology imaging is addressed to provide the platform independence and great accessibility. The system supports sharing of 3-dimensional objects. We use VRML (Virtual Reality Modeling Language), which is the de-facto standard in 3-D modeling on the Web. 3-D objects are reconstructed from CT or MRI volume data using a VRML format, which can be viewed and manipulated easily in Web-browsers with a VRML plug-in. A Marching cubes method is used in the transformation of scanned volume data set to polygonal surfaces of VRML. A decimation algorithm is adopted to reduce the number of meshes in the resulting VRML file. 3-D volume data are often very large-sized, and hence loading the data on PC level computers requires a significant reduction of the size of the data, while minimizing the loss of the original shape information. This is also important to decrease network delays. A prototype system has been implemented (*http://netopia.snu.ac.kr/*~cyber/), and several sessions of experiments are carried out*

Key Words:
Marching cubes, Decimation, Volume data, VRML, Remote medical consultation

Introduction

The former tele-medicine system was composed of bi-directional audio and video communication and sharing technology of 2D image. Such as CT/MRI, high cost medical machines are installed in large hospitals. However medium/small hospitals or graduate students are not allowed to use these for research or health care. The system, called MISS (Medical Image Sharing System) is based on this requirement. The objective of this research is development of 3D medical model sharing system using VR (Virtual Reality) and Web technology.

CT/MRI data are valuable for medical consultation. Interpretation of multiple 2D-slice images from CT/MRI needs special training. Although radiologists have these skills, they often have difficulties to communicate their interpretations to the referring physicians. Hence new approaches to visualize the 3D medical model and communicate them to physicians quickly and easily are required[8]. The applications of 3D medical images in a variety of areas are reported. For example, 3D visualization is useful for the study of complex bone structure. Dalhousie University Health Studies faculties use this technology for medical education. Vox-L Inc. developed Interactive Hologram™ which visualizes volume data from CT/MRI/PET using VR technology and Virtual Surgery™ which demonstrates real operation.

We have developed MISS (Medical Image Sharing System) which uses VRML, the *de-facto* standard in 3D modeling on the Web, marching cubes which generates surface model from volume data, and decimation algorithm which reduces model size. Because of using VRML, MISS provides the high quality 3D visualization, the platform independence and user-friendly interactivity on the Web[2].

To produce the surface model of the 3D volume data, marching cubes approach is often adopted[5]. Marching cubes is simple and robust algorithm. Many researchers have presented implementations with this approach. However this approach have some problems which are topological ambiguity, low computational complexity, segmentation of output data, and a large amount of output model. However many researches to overcome this defects are reported[5]. In this paper, most important problem of converting volume data into VRML is that marching cubes generates a large amount of model data. For VRML browsing system provides interactivity between user and 3D model, the system should load model data on memory at once. However, PC platform that has lower computing power has difficulties to support a large model. For reduction of a large amount of model data, decimation algorithm is employed to resolve the problem. This paper is composed of introduction, background theory of volume data sharing system, implementation of Web server, server performance testing, several case, and conclusion.

Background Theory

Marching cubes algorithm

Marching cubes creates triangular models of constant density surfaces from the 3D medical data. The algorithm processes the 3D medical data in scan-line. Figure 1 shows marching cubes between inter-slices.

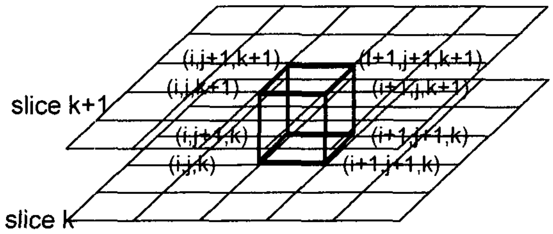


Figure 1 Marching cubes between inter-slices[9]

Since there are eight vertices in each cube and two states, inside and outside, there are only $2^8 = 256$ ways in which a surface can intersect the cube. By enumerating these 256 cases, Lorensen created a table to look up surface-edge intersections, given the labeling of cube vertices. This result in 256 possible combinations for each voxel, however this number can be reduced to only 15 different cases by flipping, or by rotation and symmetry considerations. Figure2 displays the triangulation for the 15 patterns.

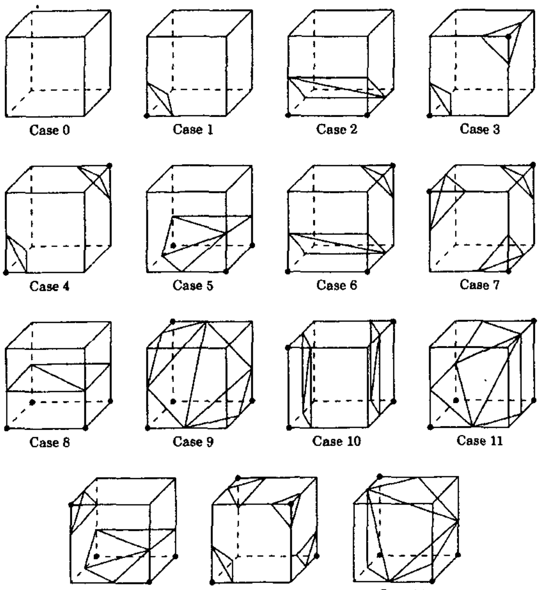


Figure 2 A case table of marching cubes[9]

For each case, a specific topology of triangles can be stored in a table. It separates classified vertices from non-classified vertices and guarantees generation of a coherent surface. The exact position of a triangle vertex is determined by linear interpolation of the threshold along the voxel edge. If the data material roughly shows local linear properties, good results in reconstruction of the original isosurface can be obtained by this method[9].

Decimation algorithm

Marching cubes produces large number of triangle meshes in which none of the triangles can be larger than a voxel. For increase of interactive responsibility, reducing the number of meshes is needed. Figure 3 presents the triangulation of 128x128x222 volume data using marching cubes. The number of triangles is 266365.

Figure 3 Triangular meshes made by marching cubes

The goal of decimation algorithm is to reduce the total number of triangular meshes, while preserving the original topology and a good approximation to the original geometry. The algorithm eliminates vertices and retriangulates the resulting hole. Vertices are not moved, and no new vertices are created. There are two criteria for deleting a vertex used by this algorithm. The criterion that is used on a vertex depends on the type of vertex. The first criterion is the vertex distance to an average plane. An average plane is calculated by using the normals, centers and areas of all the triangles that use the given vertex as a co-vertex. After finding the average plane, the distance of the vertex from the plane is determined. If a vertex is within a distance specified by the user, it is deleted and the retriangulation process of the remaining vertices is called. The second criterion is the vertex distance to an edge. In the case of boundary and interior vertices, the algorithm determines the distance to the line defined by the two vertices creating the edge of this vertex type's loop. Again, if the distance is less than a predefined criterion, the vertex is deleted.

After a vertex is deleted, the triangulation process should replace it. The triangulation process is a one or two loop process for each vertex that is to be deleted, depending on the vertex type. Triangulation on each loop must create triangles that are non-intersecting and non-degenerate. It is important to note that if a vertex can not be triangulated, then it does not have to be removed[5][7].

VRML (Virtual Reality Modeling Language)

VRML, introduced in the spring of 1995, is a language for multi-participant interactive simulation within the World Wide Web[1]. It is the intention of VRML designers to create virtual worlds networked via hyper-linked with the Web. The differing aspects of virtual worlds, including display, interaction, and Internet working, can be specified in VRML files. The objects represented in VRML can have hyper-links to other worlds, HTML documents, or other valid Multipurpose Internet Mail Extensions (MIME) types[4]. When a user selects an object having a hyper-link, the appropriate MIME viewer is launched.

This research is concerned with creating a virtual world for 3-D product models using the VRML 2.0 specification. This can support only polygons and several primitives, such as cube, cylinder, cone, java script, event node, animation, and etc. This is mainly because such restrictions can reduce the overhead in the VRML browser. Therefore, a set of polygons should approximate to a complex-shaped medical model. For the purpose of rendering and shading the polygons, their normal vectors are calculated and given to the respective polygons. This also reduces the overheads of the browser. MISS converts and processes volume data into VRML. On even PC platform, users can browse and visualize 3D medical imaging using MISS[1].

A Web client-server model for medical information sharing

In this paper, we designed a Web client-server system for 3D medical imaging following procedure. Figure 4 presents this procedure.

Figure 4 3D medical imaging process on the Web

Data acquisition

Using medical imaging system, this step samples some property in a patient and produces multiple 2D slices of information.

Image processing

Some segmentation algorithms use image processing techniques to find structure within 3D data or to filter the original data.

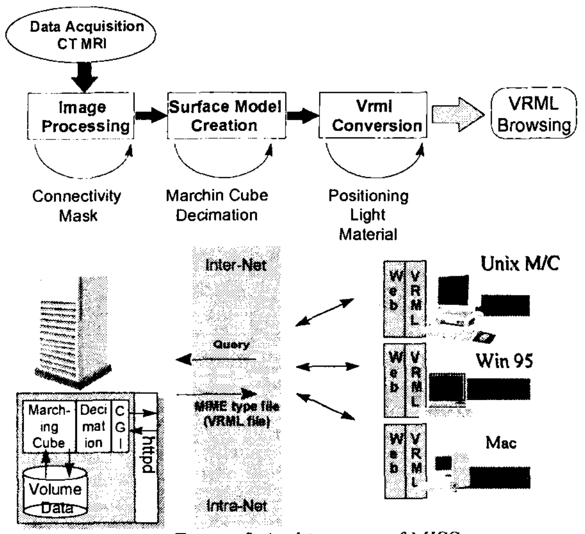


Figure 5 Architecture of MISS

Surface construction

This step generates 3D surface model from volume data. The model usually consists of 3D volume elements (voxels) or polygons.

VRML conversion

Figure 5 shows Web server-client architecture of MISS. The server generates surface model from volume data with selected density value by client, reduces the size of model using decimation algorithm, and converts the geometry of model into VRML. The server first sends MIME (x-world/-x-vrml) type of VRML and then sends VRML model[6].

VRML browsing

The medical web server is accessed using web browser. Processing method, volume data, decimation argument, and etc are specified. Then users visualize 3D medical model with VRML plug-in or external VRML browser[4]. For VRML has an advantage of platform independence, the VRML model is visualized on various platforms.

Performance Testing

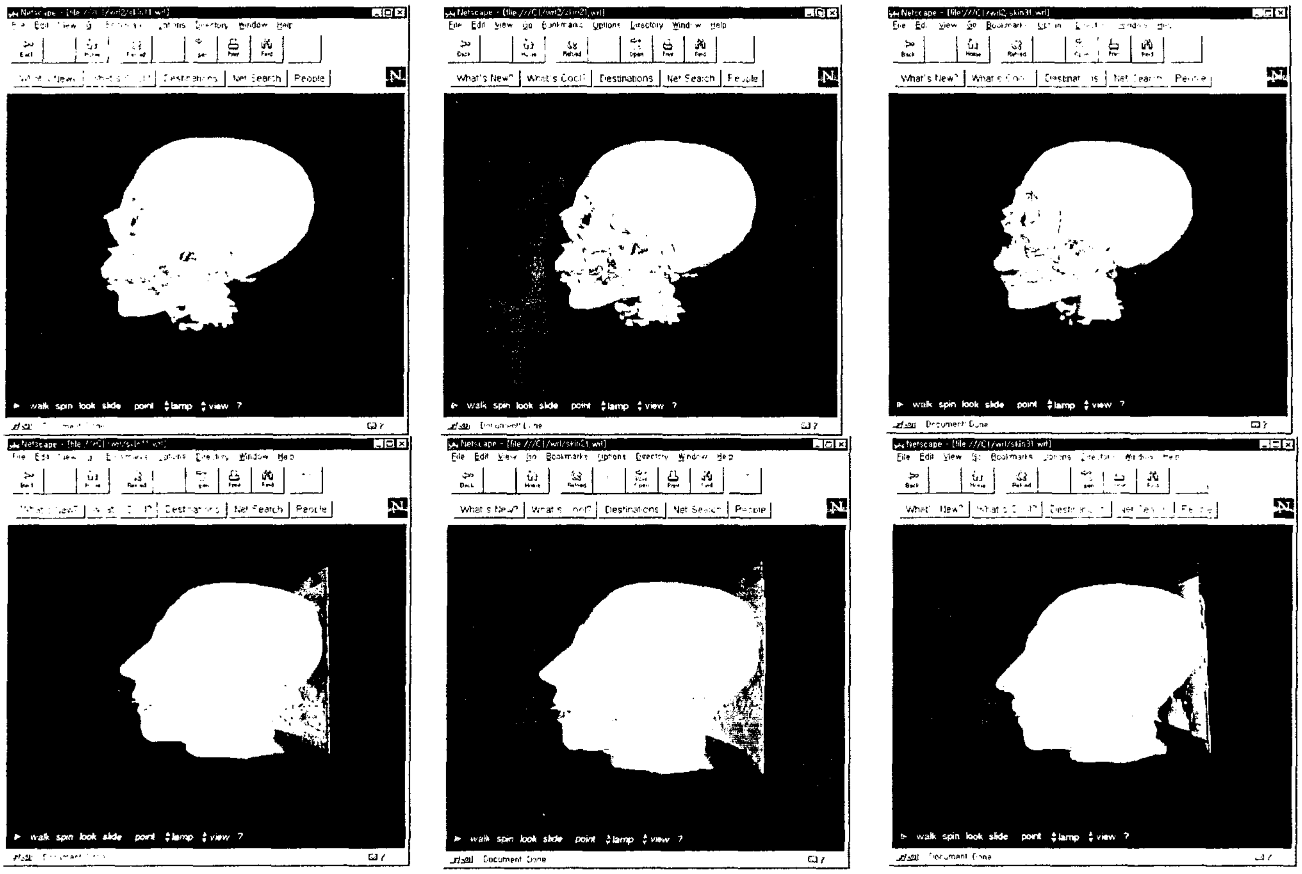
Table 1 and Table 2 show the results of performance testing for converting the volume data into VRML. The size of volume data in performance testing is 256x256x225. Table 1 presents the case that the threshold value (density) is 95.5, which is suitable for the reconstruction of bone surface. SAMPLE RATE means the size of marching cubes. M presents the case of adopting marching cubes only. MD means the case of employing both marching cubes and decimation. In case of MD, the local error-bound of decimation is 0.0002. In other case of MD2, the local error-bound of decimation is 0.002.

Table 1 Perfornce testing (bone)

Density (95.5) Resolution (sample rate)		Time (sec.)	File Size (Kbytes)	Number of Meshes
X:256 Y:256 Z:225 (1 1 1)	M	160	53665	689828
	MD	429	6171	82246
	MD2	404	2220	30221
X:128 Y:128 Z:113 (2 2 2)	M	35	12256	162208
	MD	122	3588	48081
	MD2	109	1395	19229
X:64 Y:64 Z:57 (4 4 4)	M	8	2656	35744
	MD	30	1386	19029
	MD2	24	548	7575

Table 2 Performance testing (skin)

Density (45.5) Resolution (sample rate)		Time (sec.)	File Size (Byte)	Number of Meshes
X:256 Y:256 Z:225 (1 1 1)	M	198	68311	876087
	MD	538	7571	101079
	MD2	524	3875	52430
X:128 Y:128 Z:113 (2 2 2)	M	43	15714	207236
	MD	150	4245	56651
	MD2	131	1985	26959
X:64 Y:64 Z:57 (4 4 4)	M	9	3200	42756
	MD	34	1601	21752
	MD2	27	631	8579

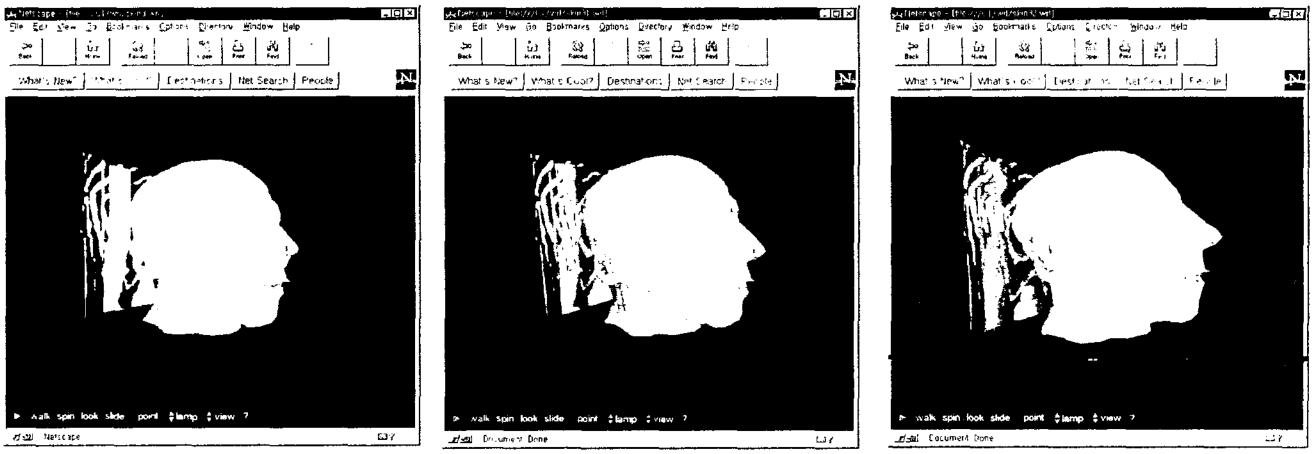


(a) SAMPLE 1 1 1 MD

(b) SAMPLE 2 2 2 MD

(c) SAMPLE 4 4 4 MD

Figure 6 Comparison of SAMPLE RATE



(a) SAMPLE 4 4 4 M

(b) SAMPLE 4 4 4 MD

(c) SAMPLE 4 4 4 MD2

Figure 7 Comparison of decimation

Table 2 also presents the case that the threshold value (density) is 45.5, which is suitable for the reconstruction of skin. The result is equivalent to the Table 1's. Figure 6 shows the figures that are created by various SAMPLE RATE's(1 1 1, 2 2 2, 4 4 4). The figure shows that if the SAMPLE RATE is larger, the model is rougher.

Figure 7 shows that the difference of the cases which are applied by M, MD, MD2. In case of M, the model looks rough. In case of MD2, the model seems smoother. However, delicate parts such as eyes can be erased.

The table 1 shows that although the case of M takes shorter, the file size and number of meshes are larger. In case of MD and MD2, it takes 3-4 times more, however the file size and number of meshes are reduced to 10%~50%. In case of MD2 (0.002), it takes shorter and the file size and number of meshes are smaller than the case of MD (0.0002).

Implementation

MISS consists of a Web server and clients. A Web server is installed in Sparc20 (RAM: 96MB). A Web client is Pentium 150(Ram: 64MB). The Netscape as a Web browser and Cosmo player 1.0 as a VRML browser is used. In web server page, volume file, start slice, end slice, decimation error rate, reduce rate, SAMPLE RATE can be selected. User can visualizes a half of skull by selecting start slice and end slice. Figure 8 presents carotid and bronchus model of a half of skull.

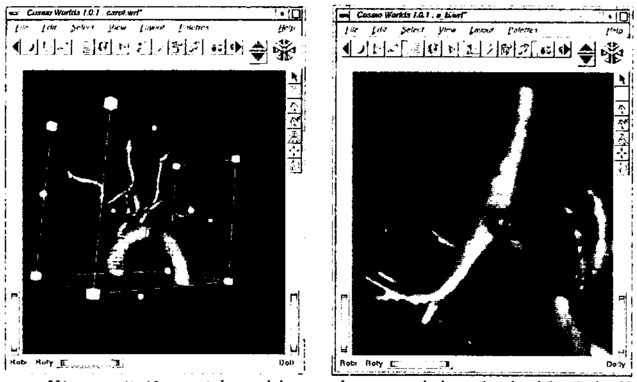
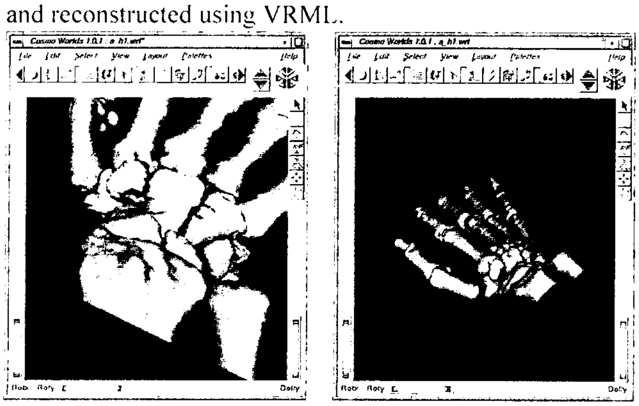


Figure 8 Carotid and bronchus models of a half of skull

Figure 10 shows the complex bone structure of hand. Each bone of hand is segmented from original volume data and reconstructed using VRML.



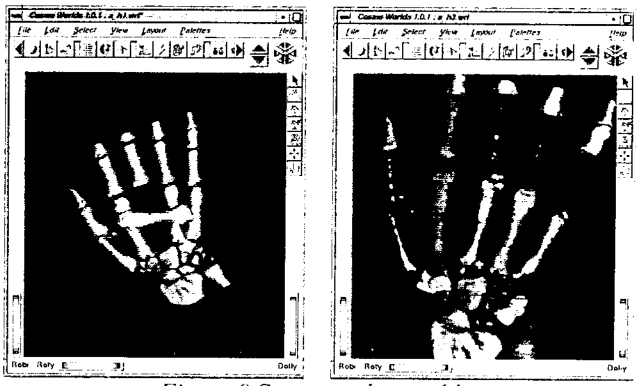


Figure 9 Segmented carpal bones

Conclusion

There are many medical areas that this paper can be applied to, for example, medical education, virtual human model, implants modeling, medical simulation and manufacturing system, 3D virtual surgery, tele-medicine, and etc. The paper presents the way to share the medical data using Web technology and 3D visualization on PC. A hospital without a radiologist or a hospital at island easily uses MISS for remote X-ray or CT/MRI imaging consultation. Further research areas are animation of respiration, circulation of blood, and movement of heart, 3D ultrasound visualization.

Reference

[1] N.K. Kim, C-Yong. Kim, Y. Kim, S-H. Kang, Development of volume data 3D visualization system using Web, *Korea CAD/CAM Engineer Society proceedings* ,pp. 1997

[2] ISO/IEC CD 14772, The Virtual Reality Modeling Language Specification Version 2.0, "http://webspace.sgi.com/moving-worlds/spec/", 1996

[3] C. Montani, R. Scateni, R. Scopigno, Discretized Marching Cubes, 1994

[4] Common Gateway Interface, http://hoohoo.ncsa.uiuc.edu/cgi/intro.html, 1995

[5] Hugues Hoppe, Tony DeRose, *et al.*, Mesh Optimization, *Computer Graphics (SIGGRAH 93 Preceedings)*, pp. 19-26, 1993

[6] Mark G., Mime Overview & Technical Summary, 1995

[7] Matthias Eck, Tnoy DeRose, et al, Multiresoultion Analysis of Arbitrary Meshes, *Computer Graphics (SIGGRAH '95 Proceedings)*, pp. 173-182, 1995

[8] S. Samothrakis, *et al*, WWW Creates New Interactive and Collaborative 3D Graphical Environments for Medical Research and Education, *European Congress of the Internet in Medicine*, "http://www.mednet.org.uk/mednet/me20. htm" ,1996

[9] William E. Lorensen, Harvey E. Cline, Marching cubes: A High Resolution 3D Surface Construction algorithm, *Computer Graphics*, Vol. 21, No. 4, 1987