The Visible Human Slice Web Server: A first Assessment

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ABSTRACT

The Visible Human Slice Server (*http://visiblehuman.epfl.ch*) started offering its slicing services at the end of June 1998. From that date until the end of May, more than 280'000 slices were extracted from the Visible Man, by laymen interested in anatomy, by students and by specialists. The Slice Server is based one Bi-Pentium PC and 16 disks. It is a scaled down version of a powerful parallel server comprising 5 Bi-Pentium Pro PCs and 60 disks. The parallel server program was created thanks to a computer-aided parallelization framework, which takes over the task of creating a multi-threaded pipelined parallel program from a high-level parallel program description. On the full blown architecture, the parallel program enables the extraction and resampling of up to 5 colour slices per second. Extracting 5 slices/s requires to access the disks and extract subvolumes of the Visible Human at an aggregate throughput of 105 MB/s. The publicly accessible server enables to extract slices having any orientation. The slice position and orientation can either be specified for each slice separatly or as a position and orientation relative to a previous slice. This contribution gives a first assessment of the slice access capabilities offered by a Java applet and possible future improvements. In the very near future, the Web Slice Server will offer additional services, such as the possibility to extract ruled surfaces and to extract animations incorporating slices perpendicular to a user defined trajectory.

Keywords: Parallel Web Server, Digital Anatomy, Visible Human, Volume Visualization, Slice Extraction

1. ARCHITECTURE OF THE SERVER

Visualization of 3D tomographic images by slicing, i.e. by intersecting a 3D tomographic image with a plane having any desired position and orientation is a tool of choice both for learning and for diagnosis purposes.

A Visible Human Slice Server has been developed, which offers to any Web client the capability of interactively specifying the exact position and orientation of a desired slice (Fig. 1) and of requesting and obtaining that slice from a 3D tomographic volume, made of either CT, MRI or cryosection images (digital color photographs of cross-sections). For interactive slice position and orientation, a miniature 3D version of the full image is used.

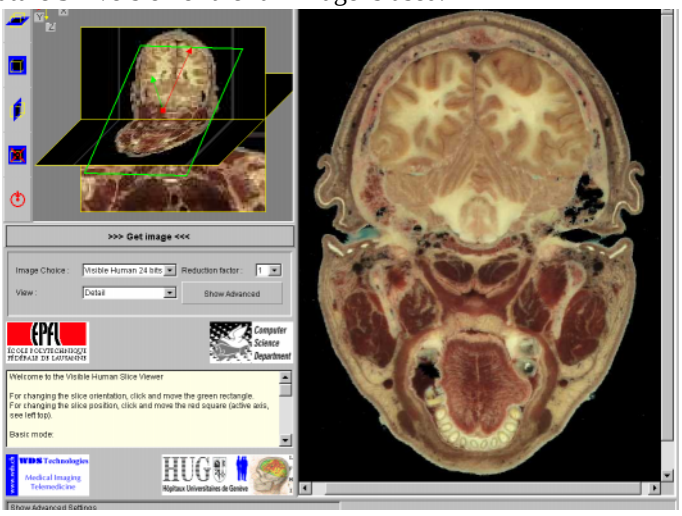

Fig. 1 Selecting an image slice within a miniaturized 3D tomographic image (Java applet)

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Accessing and extracting slices from the 3D Visible Human volume[1] (Visible Man or Woman) requires large storage space (around 13 GB) and high processing power. The Visible Human Slice Web server runs on a scaled down version of a parallel architecture comprising 5 Bi-Pentium Pro PCs with 60 disks and a client PC. The PCs are interconnected through a Fast Ethernet switch (Fig. 3).

The Visible Human volume is segmented into volumic extents of size 32x32x17 (51KB for colour) which are striped over up to 60 disks residing on up to 5 different PC's (full-blown architecture). The Visible Human slice server application consists in translating a slice access request into pipelined parallel sub-volume access and slice part extraction/resampling requests (see Fig. 2). The retrieved resampled slice parts are then merged into the final slice, which is compressed by the Web server and sent to the Web client.

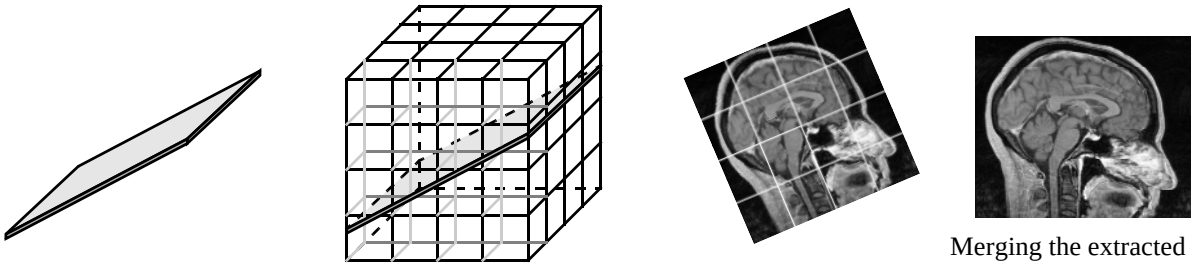

Fig. 2 Extraction of slice parts from volumic file extents

The parallel slice server application was synthesized thanks to the CAP parallelization tool and to the parallel file system components which enable building pipelined-parallel applications combining high-performance computing and I/O intensive operations[2].

The parallel slice server application consists of a server interface residing on the client PC (or on the Web Server PC) and of server processes running on the server's parallel PCs. The server interface interprets the slice location and orientation parameters defined by the user and determines the image sub-volumes (extents) which need to be accessed. It sends to the concerned servers (servers whose disks contain the required extents) the extent reading and image slice extraction requests. These servers execute the requests and transfer the resulting slice parts to the server interface, which asssembles them into the final displayable image slice (see Fig. 3). The parallel slice server application is described by the diagram shown in Figure 4.

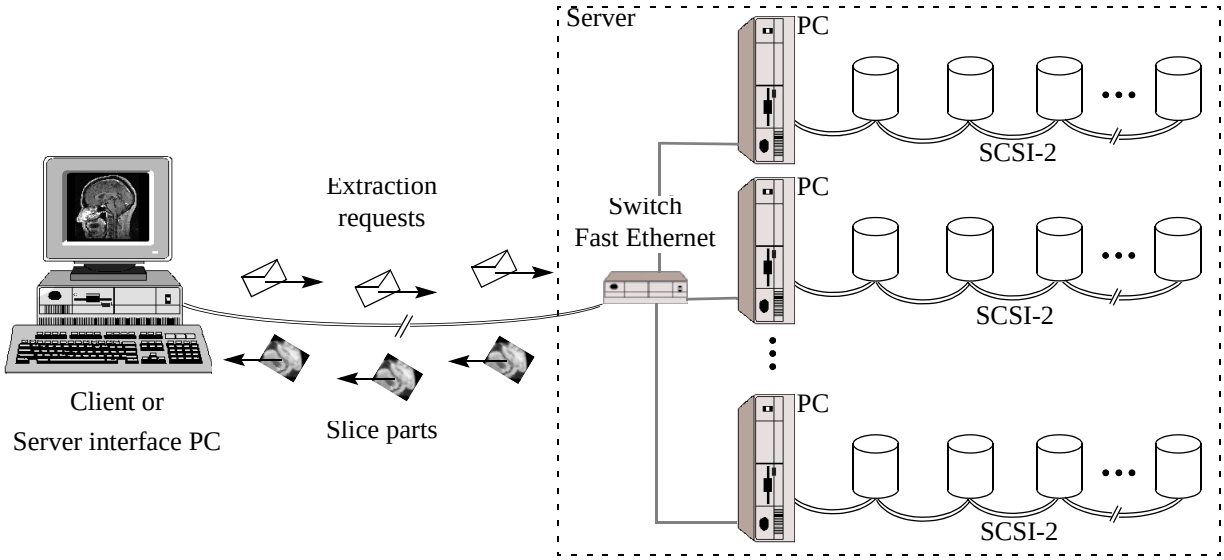

Fig. 3 Sending the slice extraction requests and receiving slice parts.

The server's performance has been tested when striping the Visible Human (male dataset) onto 1 to 5 Bi-Pentium Pro PC's and onto 1 to 12 disks per PC (max. 60 disks). Fig. 5 shows the number of extracted 512x512 colour slices per second for various configurations. Each slice access request requires approximatively 437 extent (sub-volume) access requests (22 MBytes). For all the server configurations, disk I/O bandwidth is always the bottleneck (effective single disk throughput for 51KB blocks: 1.88 MBytes/s). With 4.8 image slices/s, the server interface PC is able to receive from the Fast Ethernet 7.8 MBytes/s of image slice data. These performances are close to the performances offered by the underlying hardware, operating system (Windows NT) and network (TCP/IP over Fast Ethernet).

The scaled down architecture offering its slice extraction services on the Web comprises a single Bi-Pentium II and 16 disks. It runs all the system's functions: Web server, server interface, extent server and compute server (Fig. 4). This server is dedicated to the service of Web requests and offers an access throughput of approximatively one slice per second.

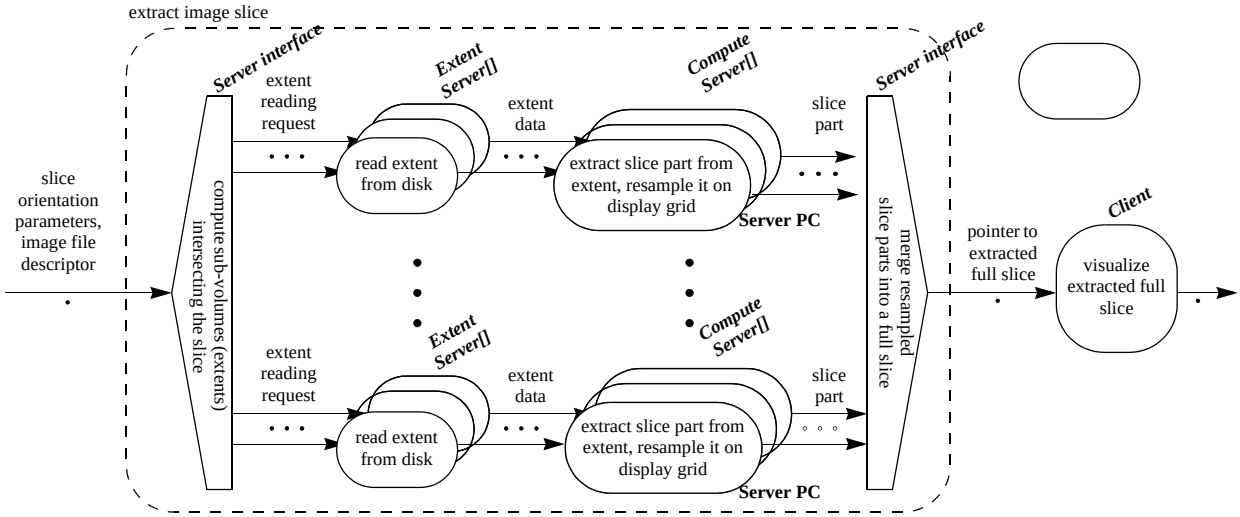

Fig. 4 Graphical representation of the pipelined-parallel plane extraction and visualization application

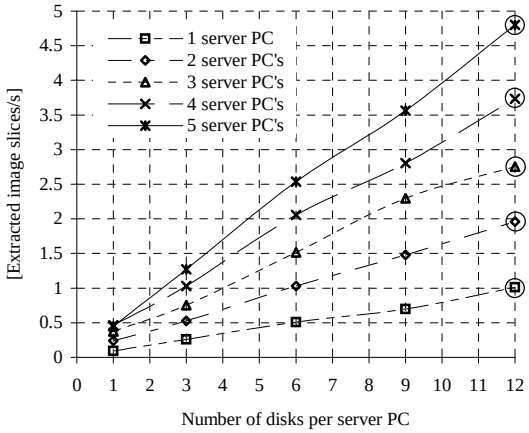

Fig. 5 Slice extraction performance under various configurations, without disk caching

The scaled-down version of the server architecture is interfaced to the Web server using the FastCGI protocol[3]. A Java applet runs on the Web clients and enables users to specify slice position and orientation and to generate access requests. Replies of the Web server are compressed (JPEG) and are sent back to the Web clients for display. The Web interface is operational at *http://visiblehuman.epfl.ch*.

2. A FIRST ASSESSMENT OF THE WEB SLICE SERVER

2.1 Visitors

From the end of June 1998 to the end of May 1999, more than 280'000 slices have been extracted from the Visible Man. Since the response of the server is quick (approx. 1 second), most of Web clients take the opportunity to extract a few slices (mean number of extracted slices: ~5). A small percentage of visitors, specially interested in anatomy, for example physicians and radiologists, extract within a single session between 20 to 200 slices (see comments in the Annex). The access statistics also show that the Visible Human Slice Server is sometimes used for teaching purposes: in autumn 1998, approximately ten PCs from the same sub-network were extracting hundreds of slices simultanously on Fridays, between 7h00 and 9h00.

2.2 User interface

The interface for specifying the slice parameters, i.e. the slice center and the slice orientation comprises a *mouse driven interactive* mode (definition of slice center and orientation on a miniature view), an *absolute* mode and a *relative* mode.

In the *mouse driven interactive* mode, the user may move the center of the slice according to the currently active axis *x*, *y* or *z*. He may change the orientation of the slice by moving the mouse. A *horizontal* mouse displacement within the 3D miniature image window varies the position of the slice normal vector extremity along a horizontal circle (circle located parallel to the *xy* plane). A *vertical* mouse displacement varies the position of the slice normal vector extremity along a vertical circle (located parallel to the *yz* plane). By successive combinations of horizontal and vertical mouse displacements, one may orient the normal vector as desired.

The *absolute* mode (Figure 6) is useful for specifying in the Visible Human's coordinate system the coordinates of the slice center and an absolute slice orientation, expressed as the orientation of the normal vector (Δx, Δy, Δz or θ, ψ). Absolute coordinates and orientations can be saved. If the same coordinates are again entered, exactly the same slice will be extracted. The main comment made by specialists in anatomy is to increase the resolution of the miniature image in order to have more information about the exact location and orientation of the slice to be extracted.

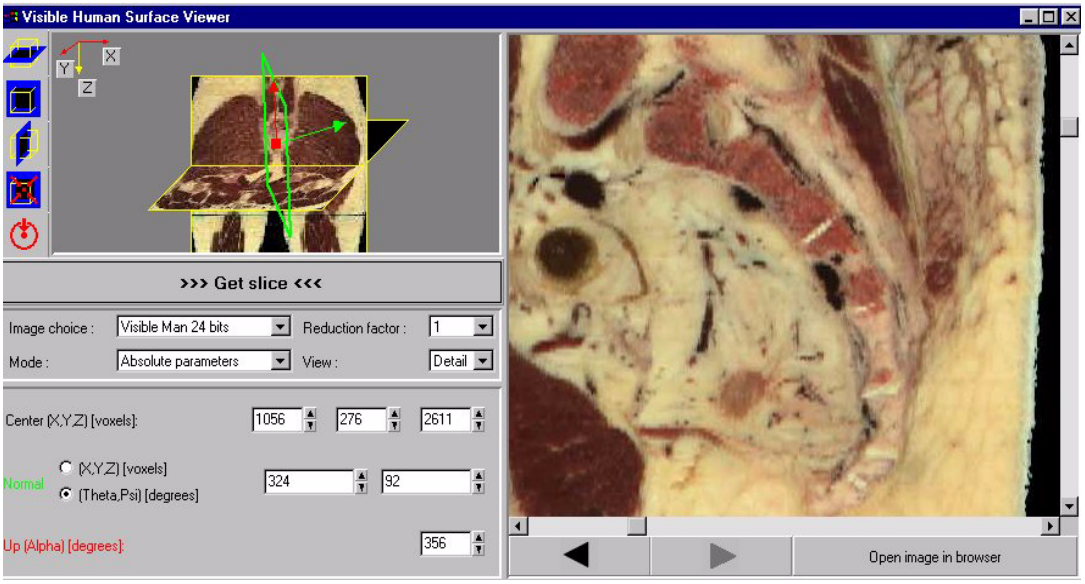

Fig. 6 Interface for absolute mode

The *relative* mode is the most useful mode for students and specialists in anatomy: on a previously extracted slice, the user may specify a new center and a rotation axis (Fig. 7). By displacing the center, he may obtain a slice in the same plane as the previous slice, but translated. By specifying an explicit rotation angle or simply a perpendicular slice, he may get a slice whose orientation

is relative to the orientation of the previous slice. Furthermore, he may specify a translation along the normal of the current slice, i.e. ask for a parallel slice at a certain distance from the current slice.

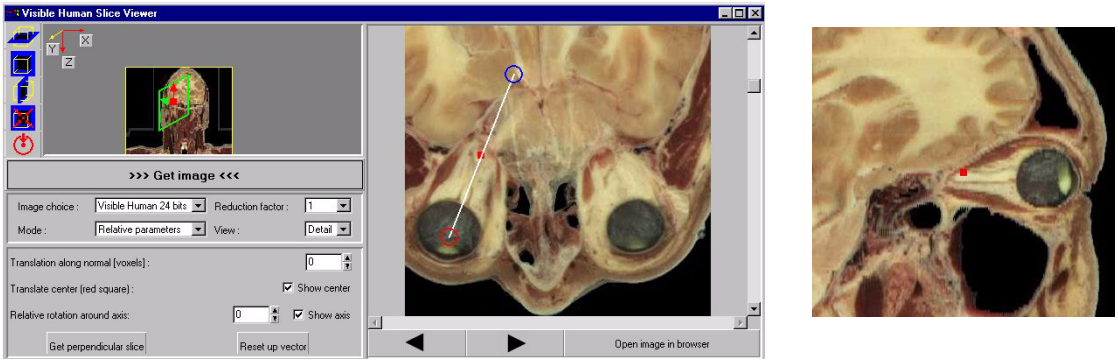

Fig. 7 Extracting a perpendicular oblique slice in relative mode

3. CONCLUSIONS

The success of the Visible Human Slice Web Server exceeds our expectations. It attracts people from various backgrounds and specialities. In particular, it provides valuable services as an educational and research tool. Feedback from users is enthusiastic (see annex). We are currently developing additional services in order to allow users to also extract ruled surfaces from the human body. Furthermore, we intend to offer users the possibility of specifying a path within the human body and to extract all slices perpendicular to the trajectory in order to generate an animation. Such an animation will give users a means of exploring parts of the human body in 3 dimensions.

REFERENCES

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3. FastCGI: A High-Performance Web Server Interface, http://fastcgi.idle.com/

Annex: Feed-back from visitors of the Visible Human Slice Web Server

“Your web site delivers exactly what it promises! A rare event in the net. As the co-chairman of the International Continence Society Standardisation subcommittee of imaging I am very excited by your web site....”, Andrea Tubaro, Division of Urology, Department of Surgery, L'Aquila University School of Medicine, 67100 L'Aquila, Italy

“To whom this may concern, I think this is a fabulous thing, though a bit macabre, given the origin of the images. As editor in chief of the Medical Tribune in Austria, my question is: is there a way of downloading these pictures? And how much would it cost to do so? Let me know. Thank you”, Dr. Norbert Hasen-Föhrl, Chefredakteur Medical Tribune, Oesterreich, Am Stadtpark 3, A-1030 Wien

“This is really fantastic, slicing through the body. Being an anesthesiologist-intensivist, I'm in the process of learning TEE (transesophageal echocardiography). With sound, you slice through the heart and big vessels. I was only able to obtain slices through the head. How do I get slices through the thorax / heart ? Thank you for this beautiful and very useful project”, Dr HHM Korsten

“I am a prof. of Orthopaedic Surgery in Ain Shams University of Cairo, Egypt. I have been helping a candidate to get naked eye sections of the intervertebral discs in different levels, I came to use your slicer and found it extremely versatile and fast. I am thouroghly impressed by your work, a great acheivment in the arena of medical imaging. Congratulations.” Timour El-Husseini, MD

“..the visible human is amazing.. so much to learn from and definitely a most innovative step in medical technology. I am a student at the College of William and Mary working on some cancer research and was fortunate enough to come across your website. It has helped greatly...”, Betina Chan

“A most wonderful and useful resource. I am truly impressed. Thank you for providing this outstanding resource. The best educational use of the World Wide Web that I have seen to date”, Jan Kessler

“I am a physician in Shanghai, China. I have access to your Visible Human Web Slice server. It is wonderful. We can navigate within the human body now. I think all physicians will be appreciate your Web site”, Shuchun Ma, MD & Ph.D, Department of Gastroenterology, Changzheng Hospital, Shanghai 200003, P.R.China

Your viewer is completely amazing! I am the art director for the Sci Fi channel in the US and am very interested in working with you on an upcoming project. If there is anyone there that could get back to me about some imaging requests I would be most grateful. Very best regards, Todd Mueller, Art Director, Sci Fi Channel

Hello visible human project, I am Michiel and I would like to send you my compliments in achieving this great internet site. I am a medical student and I think this is the most fascinating way to learn the anatomy of the human body. It's also a great interface you are using to create your own slices. I hope all anatomy classes in the future will be supported by this kind of computer programs. Michiel

“Hi visible human, You did a good job! I want to know if it is possible to recive a description of each organ or bone with the Surface Viewer?” Yvonne

“Eine sehr gute Seite, interessant, faszinierend. und bewegend zugleich Vielleicht sind auch ein paar Informationen über die Person zuerhalten evtl. ein Foto oder eine Art Lebenslauf ?”, H. Vosse

“Génial pour revoir son anat juste avant les exas !!! Je n'ai certes rien compris à l'explication technique, mais je crois que c'est là une prouesse !!! BRAVO à toute l'équipe qui a travaillé la-dessus ! Vive l'EPFL !!”, Pafin

“Vous avez un truc pour me rembobiner la langue ??? C'est magnifique ! Toutes mes félicitations !!!”, Guillaume