Collaborative Systems for Pathology Applications

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Abstract: Use of collaborative tools is essential in health applications, especially pathology. This paper presents the results of a huge-size image data collaborative system based on SSVS©, suitable for telepathology work, which can be implemented in any system working with large images. Quality, image stitching performance in the JPEG200 wavelet domain and image viewing performance were analyzed.

Keywords: Collaborative systems, telemedicine, SSVS®, JPEG2000, image stitching.

INTRODUCTION

In telemedicine and distance health applications the use of collaborative systems is essential [1-5]. Employed tools include E-learning/E-coaching [6], online device maintenance [7], image sharing[1] [9-10], health-grid [2] or even virtual procedures, including not only surgery but also virtual autopsy [10]. These tools are based on multi-agent technology and in a semantic web environment, with telemedicine ontology such as that developed by our group [1, 11].

In this paper we present the results of a huge-size image data collaborative system particularly suitable for telepathology, although it may also be applied to any system that employs large images.

Our system is based on Small Size Virtual Slide (SSVS©)[1] images, which are relatively small-size-low-power digital images, capable of supporting a high level of zoom. For collaborative purposes, the images placed in the server are composed of individual fields of view (FOV) of the specimen stitched and compressed in JPEG2000 format due to its advantages on management and size[1] [9, 10].

The quality, image stitching and viewing performance are analyzed in this paper.

MATERIAL AND METHODS

The present study used SSVS©, described elsewhere, for the analysis of quality and viewing performance.

Image Acquisition

Image acquisition was performed on a specifically designed software (Texcan-II® [12]) using an AVT Oscar CCD camera of 3272 x 2469 pixels, 12-bit color depth, coupled to an Olympus BH-2 with a 4x objective S-Plan N.A. 0.13 and a relay tube NFK 2.5x LD of 125. Image sharpness was obtained with the zoom focus© technique [12].

Captured FOVs were classified in two different sets: I) images with dark corners (*vignetting* due to differences among CCD size and microscope field projection); II) without vignetting (border correction).

Image Stitching

Stitching was performed using two commercial products and our own software application.

Commercial products were: Panavue Image Assembler® [13] and Autopano Pro® [14], which provide desirable features for supporting pathology images such as very large file handling (up to 100,000 x 100,000 pixels, 16-bits per channel color) and automatic mosaic stitching.

Our own software was built on Kakadu 5.2 library [15]. This application performed image-stitching in the wavelet domain (DWT-Discrete Wavelet transformation) of JPEG2000 images[1] [9, 15].

Collaborative System

A collaborative system was built using the Kakadu 5.2 [16] software toolkit, integrated by a JPIP-server and a viewer based on JPEG2000 Internet Protocol [17].

Quality Control

Image quality was evaluated according to presence/absence of artifacts in the stitching process as listed in Table **1**.

Table 1. Image Artifacts Detected on SSVS©

S. No.	Image Artifacts	Description
1	**Dark Spots**	Presence of dark areas due to incorrect image blending
2	**Inadequate Image Blending**	Image “phantoms” (pixel displacements, erroneous color register)
3	**Misalignments**	Partially o totally unmatched images
4	**Image Straightening**	“wavy” assembled image; image distortion similar to waves, due to incorrect alignment of capturing device
5	**Image Distortion**	General image distortions, mainly due to stitching algorithm design or incorrect software parameter setup

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Image stitching performance was evaluated, analyzing the processing time plotted against number of image FOVs as shown in Fig. (**1**). Image viewing performance was also analyzed according the function shown in Fig. (**2**).

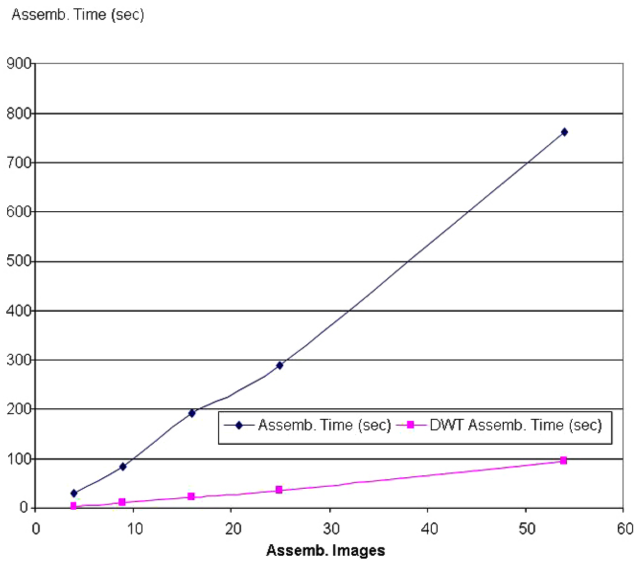

Fig. (1). Stitching performance: **a**) Using commercial products; **b**) stitching in the JPEG2000 DWT domain.

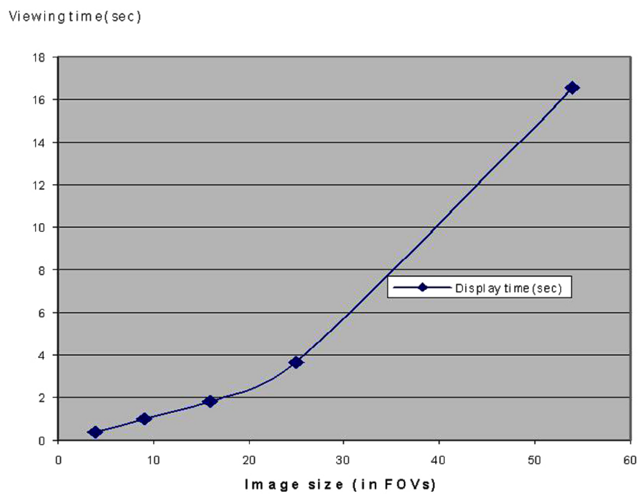

Fig. (2). Image viewing performance.

RESULTS

The number of images with and without vignetting (set I versus set II) are shown in Tables **2** and **3**.

Table 2. Image Samples for Stitching Experiments (1cm^2 / Each Set)

	Set I	Set II
Number of images (by set)	25	36
Dark/unfocused borders on each image	Yes	No
Size image component	3272 x 2469	2618 x 1787
Bit color depth / pixel	24	24
Uncompressed image (KB)	23,660	13,710

The quality control of the image artifacts is shown in Table **4**.

Stitching performance is shown in Fig. (**1**) and viewing performance in Fig. (**2**). The stitching process in DWT domain runs, on average, more than 8 times faster than naïve uncompress-stitch-compress algorithms, whereas viewing performance in this experiment showed a non-linear tendency on the number of image components.

DISCUSSION

The use of collaborative environments in the area of health care is gaining ground with the ever-increasing implementation of telemedicine.

Fields of collaboration are image sharing, common diagnosis with images and virtual reality or enhanced imaging. These involve managing huge amounts of large-size images demanding techniques for an efficient handling of storage and transmission such as the ones included in the new DICOM standard versions using JPEG2000.

When images require composition or stitching as is the case with virtual slides in pathology, the problem increase. The present study showed an improvement in storage and distant retrieval of pathology images built with the SSVS© technique.

The main performance problem with commercial products is related to image handling, which need to be uncompressed before stitching. We stitched compressed JPEG2000 images directly on the DWT spatial-frequency domain. This approach together with alternatives such as code-block and precinct level stitching has been previously described [15]. As shown in Fig. (**1**), DWT stitching is more than 8 times faster than stitching with a naïve algorithm (uncompressing-stitching-compressing).

Secondly, performance is also influenced by test-bed RAM size, hard disk transfer rates and virtual memory management. In fact RAM access is 10^3 times faster than the fastest hard disks currently available. Greater RAM available implies accelerated stitching process because the operating system does less *paging* (disk accesses) for appropriate virtual memory management.

However, RAM cannot be expanded in an unlimited way. The 32-bit computer bus architecture only allows up to 4GB RAM, furthermore reduced by installed devices and other operating system features [19]. The 64-bit computer bus architecture provides enough capacity to address RAM/file size beyond 4GB, thus simplifying whole slide image stitching.

The complete size of a tiled image should not significantly influence transmission performance and image browsing. The reason is that only an area is transmitted over the network. Experiments with different JPIP servers and JPIP-compliant viewers and very large files are recommended to check whether the non-linear tendency shown in Fig. (**2**) is related to file size or other factors (i.e.: network load, OS virtual memory management or particular JPEG2000-JPIP implementations).

As shown in the results, our system provided adequate and efficient performance, allowing the use of portable or ultra-mobile computers equipped with portable high-

Table 3. Features of the Assembled Image Sets

	Average Size of Uncompressed SSVS (MB)	Average Size of Lossless J2K SSVS (MB)	Compression Factor
Set I	540	227	2.4:1
Set II	426	193	2.2:1

Table 4. Artifacts Detected

	Panavue ImageAssembler®		Autopano Pro®		DWT Stitching	
Image artifacts	**Set I**	**Set II**	**Set I**	**Set II**	**Set I**	**Set II**
Dark Spots	dark areas in FOV corners	No	No	No	No	No
Inadequate Blending	Grid-like shadows (GLS). Light differences among FOVs	GLS Light difference Phantom borders	Image phantoms and faded areas.	Image phantoms and faded areas.	Phantom borders	Phantom borders
Misalignment	Empty fields (no match)	Empty fields (no match)	No	Empty fields (no match)	No	No
Straightening	1degree image skew.	No skew	No skew.	Wavy. Missing areas.	No skew	No skew
Distortion	No	No	Slight spherical distortion	Slight spherical distortion	No	No

resolution cameras to capture and display the images to be shared [20].

The technique presented here is unique and not reported in the literature that particularly works with virtual slide images of several Gigabytes [21]. Similarly, stitching images in the wavelet domain facilitates computing and increases the speed of building and sharing images as shown in Fig. (**1**).

In summary: The SSVS© technique with stitching in the DWT domain facilitates storage (due to the small size) and tele-consultation.

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