A Web-Based Telepathology Framework for Collaborative Work of Pathologists to Support Teaching and Research in Latin America

Darwin Díaz[1], Germán Corredor[2], Eduardo Romero[2], and Angel Cruz-Roa[1](✉)

[1] GITECX Research Group, AdaLab Research Seedbed, Universidad de los Llanos, Villavicencio, Colombia
{darwin.diaz,aacruz}@unillanos.edu.co

[2] CIM@LAB Research Group, Universidad Nacional de Colombia, Bogotá, Colombia
{gcorredor,edromero}@unal.edu.co

Abstract. Early diagnosis in cancer is very important for an appropriate treatment and effective recovery in some cases. The biggest problem in developing countries, such as Latin America, is the delay of diagnosis because poor availability of health services in remote regions and lack of pathologists who are concentrated in main cities. In this context, this paper presents a web-based telepathology framework for collaborative work of pathologists. The evaluation was addressed to analyze the computational performance in terms of time response when several and concurrent simulated user's navigations of whole-slide images are performed. The preliminary results show that the framework is able to support concurrent users with an average response time of 10 s when navigations is performed at the same magnification, which increases until 35 s in average when navigation includes changes of magnification.

Keywords: Digital pathology · Telepathology · Whole-slide imaging

1 Introduction

For diseases such as cancer, early diagnosis is a very important factor to guarantee an appropriate treatment and an effective recovery in tractable cases. An important problem in developing countries (e.g., Latin America) is the lack of access to health services and specialized personnel in medical centers with the capacity to handle the different phases of pathology: digitization of slides, diagnosis assisted by pathologists, prognosis, and treatment [6].

Technology advances have been successfully incorporated in health care in the last decades. In the pathology context, tissue sample scanners from different providers have enabled the digitalization of histopathology samples into whole-slide images (WSIs), thereby boosting the area of digital pathology and cancer research [5]. Unfortunately, slide scanners are still very expensive, around

N. Lepore et al. (Eds.): SaMBa 2018, LNCS 11379, pp. 105–112, 2019.
https://doi.org/10.1007/978-3-030-13835-6_12

$175.000 USD, which has limited its wide use in developing countries. For this reason, some innovative alternatives have emerged such as the design and development of low-cost motorized microscope for telepathology and digitalization of pathology slides [2,7,9]. However, despite the potential benefits such technologies might offer to remote regions by means of telepathology practices, there are very few efforts to include analysis of digital pathological samples in health systems around Latin America.

The rest of paper is organized as follows: Sect. 2 describes definitions and previous works in digital pathology and telepathology. Section 3 presents the web-based telepathology framework for pathologists collaborative work. Section 4 describes the experimental setup to evaluate the framework in terms of time response versus number of concurrent users. Section 5 presents the experimental results. Finally, Sect. 6 presents some conclusions and future directions.

2 Previous Works

2.1 Digital Pathology

Digital pathology is an emerging research area defined as the set of computational and technological methods that support the different stages of the pathology workflow (See Fig. 1), including slide digitization, computer-aided diagnosis, prognosis, and treatment [8].

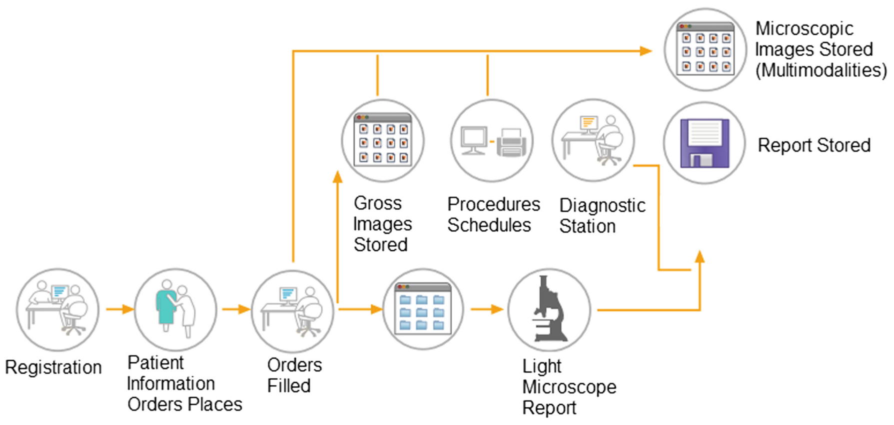

Fig. 1. Traditional pathology vs digital pathology workflow. Adapted from: [4]

2.2 Telemedicine and Telepathology

Telemedicine is defined as the provision of remote health services in the components of promotion, prevention, diagnosis, treatment and rehabilitation, by professional personnel using Information and Communication Technologies (ICT), which facilitates the access to information and offers the opportunity to reach isolated populations [1].

Technological advances for digitalization of whole slides of histopathology (using robotic microscopies and slide scanners) have opened different innovative services such as diagnosis of slides at distance, telepathology, large-scale histopathology image data bases, computer-assisted diagnosis, among others [3].

Telepathology is one of those innovative services. It is defined as the practice of remote pathology by means of the transmission of macroscopic and/or microscopic digital images through communication networks to provide diagnostic services, collaborative research, teaching, and consultations remotely. Telepathology has two main different implementations. Fist, a histopathology slide into a robotic microscope is controlled by specialized personnel remotely by the transmission of the field of view of the slide, which is visualized through a computer monitor in other location; this approach, however, demands proper connection resources. Second, the histopathology slides are fully digitized in the remote areas (where the patient is located), and then they are analyzed in a web application by pathologists at distance.

The second implementation of telepathology is particularly interesting for the Latin American context since it enables access to pathology services in remote areas where is difficult to have pathologists and the bandwidth is limited. In the next section, a web-based telepathology framework is presented; it allows users to simultaneously access, navigate, annotate, and analyze digitalized whole-slide histopathology images.

3 Web-Based Telepathology Framework

Figure 2 depicts our proposed implementation of a Web-based telepathology framework for collaborative work of pathologists. First, our solution is a Web application with a user interface (UI) based on Bootstrap[1] and Java Server Pages (JSP)[2] that provides, by authentication, access to multiple users (pathologists) using a standard web browser. The Web application comprises two main modules: (i) a whole-slide histopathology image viewer (`SlideViewer`), and (ii) a whole-slide histopathology image data resource provider (`WSIProvider`).

Whole-Slide Histopathology Image Viewer. The `SlideViewer` module is an interface between the user (who uses a web-based user interface) and the `WSIProvider` module. It displays the image regions requested by the user through the web browser. When a pathologist interacts with the user interface (panning or zooming), the corresponding image regions are requested to `WSIProvider` and then displayed.

[1] https://getbootstrap.com/.
[2] https://docs.oracle.com/javaee/6/tutorial/doc/bnaay.html.

Whole-Slide Histopathology Image Data Resource Provider. The `WSIProvider` is an interface between the `SlideViewer` module and the data resources stored in a data server. Such resources include the images (stored in different formats such as SVS, JPEG2000, or TIFF), data indexes, thumbnails, diagnostic information, and annotations. This module uses the Jasper 2.0[3] implementation for decodification of JPEG2000 images and OpenSlide[4] for other image formats.

In order to analyze the viability of this Web-based telepathology framework, an experimental setup is defined to evaluate the response times when different simulated simultaneous users navigate the whole-slide histopathology images.

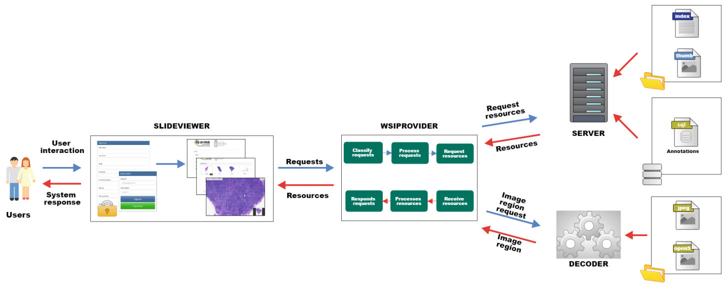

Fig. 2. Overall scheme of the proposed implementation of a Web-based telepathology framework for collaborative work of pathologists.

4 Experimental Setup

The evaluation of the web-based telepathology framework was performed in terms of response times of tile requests from the UI during the whole-slide histopathology image navigation. Four different predefined navigations were designed to evaluate the response times when whole-slide histopathology images are navigated in a concurrent manner for one or more users (1, 2, 4, 8). Each combination of a given navigation and concurrent user was repeated 10 times to calculate the average and dispersion of response times in order to analyze the stability and robustness of the web-based telepathology framework in a typical scenario with limited bandwidth and several pathologists or pathology residents exploring and analyzing different whole-slide histopathology images at the same time. All the experiments were executed in server with Debian 8 OS, 32 GB RAM, a CPU processor with 32 logic cores, and maximum memory for JVM was fixed into 20 GB.

[3] https://www.ece.uvic.ca/~frodo/jasper/.
[4] https://openslide.org/.

4.1 Performace Measure

The response time of the tile's requests of regions from the whole-slide histopathology image according to UI field-view of the web-based telepathology framework was the real time of execution of the slide navigation, or Elapsed time (E_t). The elapsed time was calculated as the difference between the initial time measurement when the navigation starts with the first set of tiles required for the initial visualization of WSI t_i and the final time when the navigation ends with the last tile required shown in the screen t_f, such as it is presented in Eq. (1).

$$E_t = t_f - t_i \tag{1}$$

4.2 Simulated Navigations

In order to evaluate in an objective manner the computational performance of the web-based telepathology framework, four different navigations were defined. According to the UI of the web-based telepathology framework, there are a fixed set of actions to explore the whole-slide histopathology images by users: (i) loading of the image, (ii) the displacement (vertical or horizontal), and, (iii) zoom-in and zoom-out in different magnifications between 0.1× and 40×. Hence, four simulated navigations were defined starting from above actions as follows:

Navigation 1. The first navigation consisted of the loading of the image at 4× magnification, as it is shown in Fig. 3.

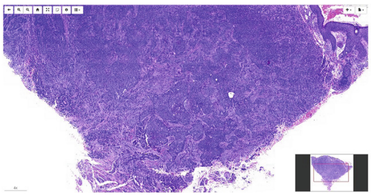

Fig. 3. Navigation 1: Load of tiles from the whole-slide image at 4× magnification.

Navigation 2. The second navigation consisted of: (i) loading the image in 4× magnification, (ii) magnification transition 4× to 10×, and, (iii) magnification transition 10× to 40×, as it is shown in Fig. 4.

Navigation 3. The third navigation consisted of: (i) the loading of the image in magnification 4×, and (ii) displacement of the central zone towards the upper right area of the image, as it is shown in Fig. 5.

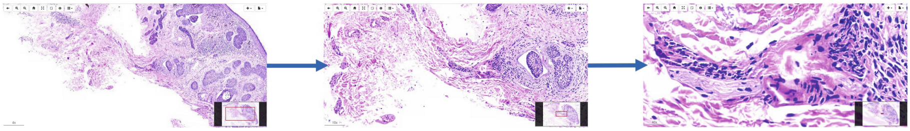

Fig. 4. Navigation 2: Load of tiles from the whole-slide image at 4× magnification, zoom-in from 4× to 10×, zoom-in from 10× to 40×.

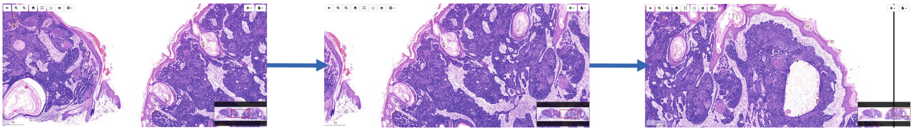

Fig. 5. Navigation 3: Load of tiles from the whole-slide image at 4× magnification and displacement of the central zone towards the upper right area of the image.

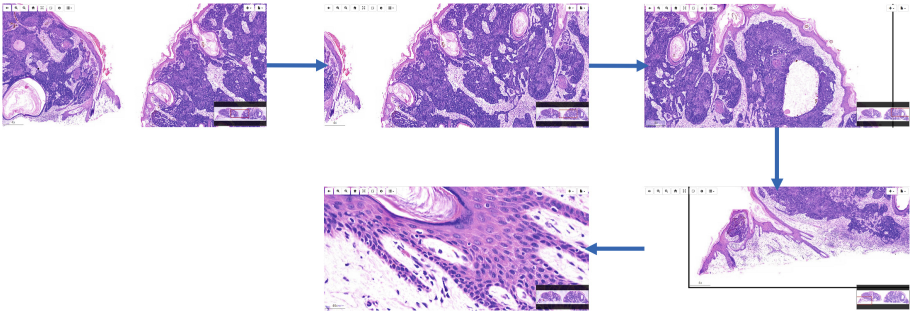

Fig. 6. Navigation 4: Load of tiles from the whole-slide image at 4× magnification, displacement of the central zone towards the upper right area of the image, jump to lower left area, and, zoom-in from 4× to 40×.

Navigation 4. The fourth navigation consisted of: (i) loading the image in 4× magnification, (ii) moving the central area towards the upper right area of the image, (iii) jumping to the lower left area, and, (iv) magnification 4× to 40×, As shown in Fig. 6.

5 Results

Figure 7 presents the experimental results for each of four navigations by comparing the number of concurrent users performing each navigation versus response time in seconds. Figure 7A shows that Navigation 1 took around of 7.5 s for 1, 2 and 4 concurrent users and close to 8.5 s in average for 8 concurrent users. Figure 7B shows increasing time for Navigation 2 with an average of 30 s for 1 concurrent user, 30.5 in average for 2 users, 33.5 in average for 4 concurrent users and 40.5 s for 8 concurrent users. Figure 7C depicts that Navigation 3 took 11.5 s

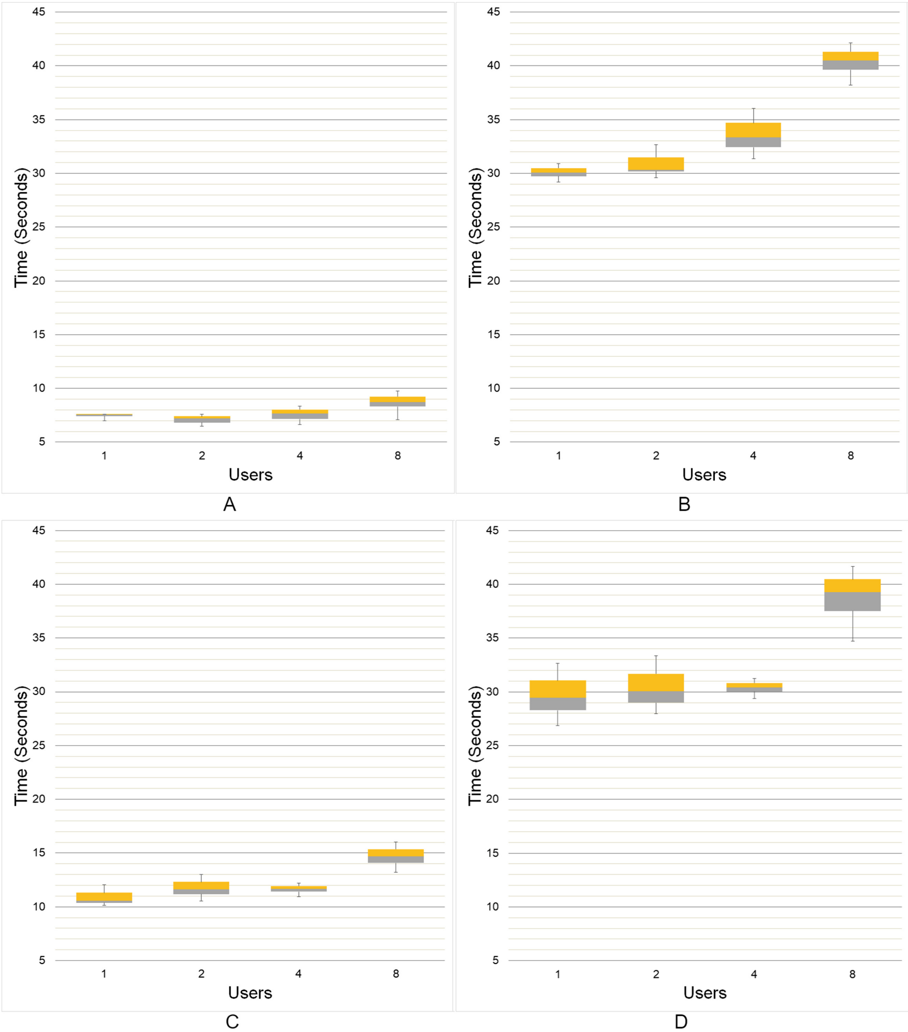

Fig. 7. Boxplots of the execution times in seconds of each navigation with a particular number of concurrent users (1, 2, 4 and 8). (A) Navigation 1, (B) Navigation 2, (C) Navigation 3, and D Navigation 4.

in average fro 1, 2 and 4 concurrent users and 14.5 in average for 8 concurrent users. Figure 7D shows that Navigation 4 took in average 30 s for 1, 2 and 4 concurrent users, whereas for 8 concurrent users took in average 39.5 s.

Therefore, Fig. 7A and C shows that the faster navigations results correspond to Navigation 1 and Navigation 3. Navigation 1 is just the load of an image at 4× magnification and Navigation 3 is the load of an image at 4× magnification and displacement from the central region towards the upper right area of the image at the same magnification. In contrast, Fig. 7B and D took more time because both Navigation 2 and Navigation 4 included changes of magnification. For instance, Navigation 2 changed the magnification from 4× to 10× and then from 10× to 40×, whereas Navigation 4 starts loading the image followed by vertical and horizontal displacements, then a jump to other unseen region and changed the magnification from 4× to 40×.

6 Conclusions and Future Directions

This paper presented a Web-based telepathology framework for pathologists collaborative work. For that, the implementations integrates different technologies and an evaluation was performed in order to analyze the capabilities for concurrent navigations from different users into whole-slide histopathology images. These results suggest that depending of the type request the response time changes. Here, displacements took less time in comparison to jumps and magnification changes. In addition, the response time increases as soon as the number of concurrent navigations are performed on the server.

Future work includes an evaluation of the framework with real pathologists from different locations, with more users working in concurrent manner over same whole-slide histopathology images and performance optimization of the queue tile's requests, by comparing multiple servers, distributed computing or GPU optimization.

References

1. Colombian Congress. Law 1419 of December 13 of 2010 (2010)
2. Cruz, A.: Data-Driven Representation Learning from Histopathology Image Databases to Support Digital Pathology Analysis, 1:164 (2015)
3. Farahani, N., Pantanowitz, L.: Overview of Telepathology (2015)
4. González López, A.M.: Las TIC como factor de Cambio. Technical report, Sescam, Satec (2011)
5. Gurcan, M.N., Boucheron, L.E., Can, A., Madabhushi, A., Rajpoot, N.M., Yener, B.: Histopathological image analysis: a review (2009)
6. Huang, C.H., Veillard, A., Roux, L., Loménie, N., Racoceanu, D.: Time-efficient sparse analysis of histopathological whole slide images. Comput. Med. Imaging Graph. **35**(7–8), 579–591 (2011)
7. Lasso, C., Vargas, C., Romero, E.: Sistema modular de telepatologia para la exploración remota de placas histopatoloogicas sobre la red renata. e-colabora (2012)
8. Madabhushi, A.: Digital pathology image analysis: opportunities and challenges. Imaging Med. **1**(1), 7–10 (2009)
9. Vargas, C., Romero, E.: Dispositivo para controlar la platina de un microscopio con la ayuda de un computador (2008)