Multimedia Surgical Sessions in a Web Environment

GRIMÓN FRANCISCA[1*],CASTAÑEDA ANTONIO[1],ESCOBAR JAVIER[1], MONGUET JOSEP[2], ESCOVAR PAÚL[3]
[1] Department of Computer Science, Faculty of Science and Technology, University of Carabobo, Carabobo, Venezuela
[2] Multimedia Applications Laboratory, Universitat Politècnica de Catalunya, Barcelona, Spain.
[3] Faculty of Health Sciences, School of Medicine, University of Carabobo. Director of the Teaching Institute of Urology, Carabobo, Venezuela.
* Corresponding author: fgrimon@uc.edu.ve; grimon.francisca@gmail.com.

Abstract: - The purpose of this study was to develop the Remote Surgery System that allows integrated multimedia sessions in either synchronous or asynchronous training, editing, evaluation and second opinion backed up by the patient's medical charts in a web environment. Method: The application was developed by a multidisciplinary team with members from the fields of health, IT, design and communications. This study can be classified as constructive research to test feasibility. The agile software development process was guided by the Extreme Programming method, using Unified Modelling Language. The features of the Remote Surgery System were generated based on surveys and interviews with users and direct observation of processes. Technical assessments of the Remote Surgery System were carried out on the Integrated Digital Backbone of the University of Carabobo between the Urology Teaching Institute facilities where the operating room and University Campus are located. Result: The performance of the application was assessed and found to be good under suitable interconnection of the network conditions. The images presented in good quality settings were adequate, with good definition of the contours and colors even when this meant a high demand on link bandwidth. Conclusion: This development provides new opportunities for interaction in telemedicine, particularly in the areas of training and obtaining a second surgical opinion in a Web environment. The system is technically feasible with high potential for medical staff training which will result in better patient care requiring surgery.

Key-Words: - Telemedicine, Health, Training, Medical Staff, Multimedia, Internet.

1 Introduction

In recent years there have been several investigations in the field of telemedicine, which can be referenced including the work of Turk [1] whose objective was to use telemedicine in the follow up of patients with burns. Shibata [2] constructed a telemedicine system using the Internet and a remote desktop. Neri [3] investigated a more efficient learning system and developed two cooperative learning strategies exploited in the system REGAL. Chen [4] studied the effectiveness of learning for students with test nursing online. Arriaga [5] developed telemedicine applications that allow to provide medical care and developing clinical practice of residents and fellows remotely. According to Syburra [6], telemedicine is the practice of medicine using telecommunications technology.

Pietro and Rafael [7], summarize the main applications of telemedicine in surgical training and education: Telementoring, Teleproctoring, Telesurgery, Teleeducation, Teleconsultation, Teleconferencing. And according to the roles defined, the Remote Surgery System (RSS) is part of a system of Telementoring, Teleeducation, Teleconsultation, Teleconferencing and partly Telesurgery and teleproctoring. These systems use the multimedia interactive services that are based on multimedia streaming techniques [8].

The factors that have contributed to the growth of telemedicine are geographical separation, logistic problems in patient care, extreme climatic conditions, the increase in primary, secondary and tertiary health care [9-11]. In the area of surgery, the quality of images transmitted over the network must meet the needs of medical professionals [12].

This research is part of the project RSS undertaken in the Faculty of Experimental Sciences and Technology of the University of Carabobo (FACYT) and the Urology Teaching Institute (IDU) in Valencia, Venezuela, in conjunction with the Multimedia Applications Laboratory (LAM) of the

Universidad Politécnica de Cataluña (UPC) in Spain.

2 Problem Formulation

The training of medical personnel in surgical techniques has always been constrained by the conditions imposed by the same environment of their activities: cost constraints, space, visibility, distance, time and opportunity [13] (just to name a few); these hinder the participation of medical personnel in courses taught in this area. In a field where knowledge and technologies evolve daily, it is vital to keep medical charts well formatted and updated in diverse surgical procedures, since this will directly affect the health and lives of patients requiring surgery for one reason or another.

Table 1. Summary of the features available on various applications. A: Adobe Acrobat Connect Pro, S: Skype, M: Moodle, Q: RSS.

Functionality	A	S	M	Q
User authentication.	✔	✔	✔	✔
Previous installation required no.	✔			✔
Management roles.	✔		✔	✔
Administer courses and facilitators	✔		✔	✔
Create permanent groups	✔		✔	✔
Administer codecs				✔
VoIP integration	✔	✔		✔
Record sessions	✔	✔		✔
Edit a saved surgical session				✔
Explore saved surgical sessions	✔			✔
Online Electronic Medical Records.				✔
Configure and submit an evaluation.			✔	✔
Shared whiteboard	✔			✔
Public messaging	✔	✔		✔
Private messaging	✔	✔		✔
File Transfer	✔	✔	✔	✔
Create a discussion topic in the forum				✔
Participate in discussion topics in the forum				✔

The users' experience of a traditional web application does not compare with the graphic interfaces of desktop client/server applications. Traditional web applications have a slow response time that depends considerably on network speed and traffic. Continuous requests must be made to the server to load a new page. The server carries out most of the data processing that is related to the business logic. Traditional web applications have restrictions that have reached their limits [14], including: process limitations (you need to browse several windows to complete a task), data limitations (complex data representations cannot be explored interactively) and feedback limitations, as ordered and continuous interaction cannot take place without refreshing the page, which reduces the smoothness of the interaction with the user [15]. In RIAs, the application is only downloaded once and the programmer is free to decide which part of the processing is carried out by the client and which part by the server. In traditional web applications, communication is always sequential, whereas in RIAs concurrent and parallel processes can be executed that facilitate smoother communication between the user, the client and the server [16]. RIAs also provide sophisticated user interfaces to represent data and complex processes or simply to enhance the appearance of the user interface (UI). Depending on the RIA technology that is used (e.g. Flex), an application may even communicate with the operating system (OS) and the hardware resources of the client computer, including the archive systems, Web cameras and other devices.

Several general applications have been developed that allow transmission, assessment and management sessions of education at various levels of complexity and functionality that have been adapted to the surgical practice training. Moreover, existing developments do not allow users to have a single application that contains the components necessary for the formation process and second opinion. The RSS brings together a variety of tools that facilitate the process and Table 1 we compare the features available for representative applications in the areas of Web Meetings (Adobe Acrobat Connect Pro), Free Web Conferencing (Skype) and Free Personal Learning Environment (Moodle) from the RSS.

There have been various training experiences to processes, second opinion and consultation, using either private or COTS platforms [17] or instructions used for this purpose [18-22]. Tests were carried out using existing network applications easily accessible (Skype, Ustream and Dropbox) with some success but with the limitations imposed functionality available [23].

3 Problem Solution

The Remote Surgery System (RSS) was developed specifically to meet the particular requirements of a specific area of distance learning as are the teaching of the practice and second surgical opinions in a synchronous or asynchronous manner, with high demand on video quality, on a single platform,

practical and easy setup and use by the end user (doctor or medical student).
The RSS incorporates in its platform the capacity to structure sessions with up to four high quality video windows which the user can simultaneously setup with live audio of all participants in the session (including the surgeon facilitator during surgery). The RSS has a number of additional standard features such as chat, forums, whiteboard, file transfer and other more sophisticated, such as recording and editing sessions, design and management of online assessments using multimedia elements and online Electronic Medical Records (EMR) [24]. incorporated into the system (with management of confidential information) [25-27]. In summary, the RSS is an information and communication system that is executed in a web environment and aimed at users with little expertise in telematics applications [28,29]. The RSS mainly uses open source technologies to create a set of applications and tools for telemedicine and tele-education. It takes advantage of the development of broadband network technology with quality of service, which enables higher education institutions and health care centres to provide training opportunities of greater quality at a lower cost [30].
In the development of the RSS applications, Rich Internet Application (RIA) techniques were used. In this research, we use the term RIA, which was introduced by Allaire [31] to refer to the combination of traditional desktop applications and web applications, to obtain the best from each one and to overcome the weaknesses in both architectures. The desktop applications that are most similar to the RIAs are client/server applications in which the business logic is located mainly in the client computer. This type of application has high computing performance as it is optimized for a specific platform. However, this affects the software portability. In web applications, the business logic is located and processed in a remote server and travels through the network in a language that the client understands.

3.1 Materials and methods.

Prior to the development of the application, a data collection process was carried out, using surveys and interviews, mainly to identify the functionalities to be implemented in the RSS. In order to evaluate the system's functions, a series of tests were designed to determine their performance with regard to the use of the network and the load on the server applications and codecs. To do this end, we use data from Adobe ® Flash Media Server Administration Console on the Operations Centre server of the Integrated Digital Backbone of the University of Carabobo (COR REDIUC) and on the console monitors in the workstations.

Fig. 1. Two planes during a test of the RSS during a live session: at the top shows the surgical act and at the bottom the participation of three urologists during one of the test sessions system.

In the tests, we used a SUN Z40 server (two 2.4 GHz, 4 GB of RAM Opteron Single Core Processors) and 3 computers equipped with audio and video receivers connected to various surgical devices. All of these elements were connected to the backbone of the University of Carabobo (UC) to 100 Mbps (Full Duplex). The server was in the Computing Department at the Campus Bárbula, Valencia, 14 kilometres from the IDU's surgical facilities. The stations that encode the videos have standard definition video capture drivers that can send videos in National Television System Committee (NTSC) format. They are connected to the university broadband network. They are situated in the reporting room adjacent to the IDU operating room.
Doctors, surgery students and the authors of this paper participated in the tests of the RSS tool. The

computers of the users and facilitators were situated in the Computing Department's Network Laboratory at Campus Bárbula, and in the IDU's Telemedicine and Reporting Rooms. Participants included three urological surgeons and 4 medical students who were interns at the IDU. Fig. 1 sample moments in which three urologists medical participate in a real test of the system. Several scenarios with different video quality were tested, these are shown in Table 2.

Table 2. Configuration of 4 scenarios of audio and video transmission for an operation. CV: Video Quality; AB: Average Bandwidth of the Channel (Mbps); D: Delay (seconds); S: Synchronize audio and video.

Scenarios	CV	AB	D	S
1 Four videos from WebCam that served as the user (320x240 @ 30fps). Dynamic Quality (Compresed), Bandwitch at 1 Mbps.	Good	22.0	<1.0	Yes
2 Four videos, 1 from a Codec (320x240 @ 30 fps), Top Quality, Dinamic Bandwidth; the other three from WebCam that served as the user (320x240 @ 30fps). Top Quality, Dynamic Bandwitch.	Good	27.0	<1.0	Yes
3 Four videos, 1 from a Codec (384x288 @ 30 fps), Dynamic Quality (Compressed), Top Bandwidth; the other three from WebCam that served as the user (320x240 @ 30fps). Dynamic Quality (Compresed) Bandwitch at 1 Mbps.	Good	33.0	<1.0	Yes
4 Four videos, 1 from a Codec (640x480 @ 30 fps), Top Quality, Dynamic Bandwidth; the other three from WebCam that served as the user (320x240 @ 30fps). Top Quality, Dynamic Bandwitch.	Bad	50.5	<1.5	No

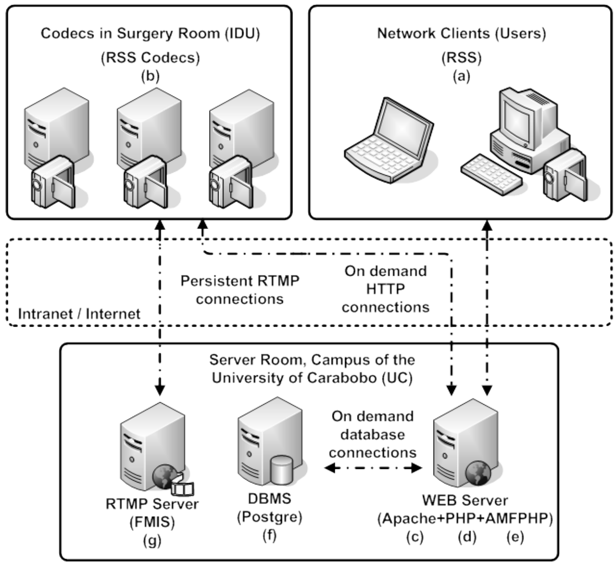

Fig. 2. Architecture and deployment of the tool's components.

3.1.1 Development platform and multimedia support.

Adobe® Flex®, which was created by Adobe®, is currently the most popular development technology for RIAs, as Flash® has long been used for graphics, animation and interactivity on the Internet. Version 3 was released with a free-code license: Mozilla Public License (MPL). The applications can be used on various modern operating systems. It can handle high definition audio and video, and real-time data and multimedia communication between clients using the Flash Interactive Server. Flash Media Interactive Server (FMIS) is used as a multimedia server, as it performs well and supports the Sorenson and H.264 codecs for video transmission. Data storage is carried out using Postgre RSS as the Database Management System (DBMS). As Flash Player can be integrated with the client's OS, the applications developed in FLEX® can access the hardware devices for audio and video capture that are managed by the computer's OS. Thus, a fluoroscope, laparoscope or any other device with an appropriate interface can be linked to the client computer that is connected to the Internet and transmit the real-time images to the web. In terms of hardware, the system has a Debian Lenny Server (Debian 5) connected to an Ethernet network at 100 Mbps (Full Duplex). Fig. 2 shows the architecture of the previously described system.

3.2 Results.

The most important functionalities to be implemented in the RSS were obtained from the field evaluations performed previously [32]. Table 3 shows the resulting functions to be implemented in the application. Another aspect incorporated into the system was patient anonymity in the evaluation sessions where clinical history is presented. The fields of information that can identify the patient were removed, allowing only the authorized treating surgeon and authorized staff to have access to the complete information in the online electronic medical records.

Table 3. Summary of the functionalities of the tool that are or are not shared by the four roles that operate the system. A: Administrator, F: Facilitator, U: User, C: Authorized.

Functionality	A	F	U	C
Configure a surgical sesión	✔	✔		
Participate in a surgical session in real time		✔	✔	
Open a EMR		✔		✔
Configure an evaluation		✔		
Present an evaluation			✔	
Administer groups		✔		
Explore saved surgical sessions		✔	✔	
Edit a saved surgical session		✔		
Create a discussion topic in the forum		✔		
Participate in discussion topics in the forum		✔	✔	
Administer codecs and video sources	✔			
Administer courses and facilitators	✔			

3.2.1 System components

A component is a piece of a system's executable and replaceable software that provides services and a set of interfaces to communicate with other components [33]. The system described here has 7 components (Fig. 2). Components (a) and (b) are called 'RSS' and 'RSS Codec', and both are developed in FLEX®. These are the client applications with which the user interacts. They are executed on computers. Component a) is an RIA that enables the user to interact directly with the system and to access and use all of its functionalities. Component (b) is a piece of software that does not require direct interaction with the user. It is executed on a computer connected to the Internet and equipped with an audio and video capture device.

It controls these resources and operates them remotely by means of component (a). The components (c), (d), (e) and (f) are Apache, AMFPHP, PHP and PostgreRSS. AMFPHP is an open source software development that translates messages coded in Action Message Format (AMF) to PHP language, which is the coding used in applications that are developed using FLEX® to send and receive data through a network. Finally, the main function of the FMIS component, which is labelled as (g), is to offer real-time communication services between different instances of (a) and (b). These services include real-time two-way audio and video transmission, on-demand video transmission, shared objects that enable the users to interact simultaneously with chat and the whiteboard, and the data that the different instances of (a) and (b) use to keep synchronized. The communication to and from (g) is coded in AMF. Therefore, (a) and (b) communicate with (g) with no need for an intermediate translator. This system uses configurable quality video transmission (that can be adapted to the network bandwidth), with signals from the various devices and equipment used in surgical operations. Thus, specialists in front of computers at remote sites that are interconnected by the network can observe and interact with the surgeon facilitator before, during and after the operation. The tool has elements for multimedia video editing and for live two-way transmission of audio and video. In addition, it uses a database manager to store information that is generated and input.

Fig. 3. A screenshot of the step to configure the elements available during the operation.

3.2.2 Software engineering.

In addition to all of the infrastructure involved and the third party open source software that was used to provide services, two complete products were developed using FLEX®: RSS and RSS Codec. These products consist of a pair of applications with which the user interacts to access all of the system functionalities. To develop the RSS, we used the Extreme Programing (XP) agile software development method, documented with a small set of Rational Unified Process (RUP) artefacts and diagrams in Unified Modeling Language (UML). As XP suggests, prototypes of the RSS product were developed and assessed by the users who considered that the final product met their requirements [34]. At all times during the development process, we considered the usability and soundness of the tool [35]. We created a product with a clear, intuitive user interface for a group of users who are not IT or internet experts.

3.2.3 Functionalities of the tool.

The tool has a system of user privileges so that each role can carry out a specific set of activities. Table 3 summarizes each role and the tool's main functionalities for each role, which may or may not be shared.

Table 4. Summary of the activities that the facilitator and normal user can carry out during a surgical operation. CP indicates that the user can perform an action but requires the permission of the facilitator. F: Facilitator, U: User.

Functionality	F	U
Share files	✔	✔
Upload an image onto the whiteboard	✔	**CP**
Erase the whiteboard	✔	**CP**
Draw on the whiteboard	✔	✔
Participate in the chat	✔	✔
Position videos	✔	
Place the video on the entire screen	✔	
Expel a user from a surgical session	✔	
Private chat with users	✔	
Speak directly to a user	✔	

When a live surgical operation is configured, the facilitator can choose to activate a set of elements that will be present throughout the operation, as shown in Fig. 3. Depending on their role, users have access or not to certain privileges during a surgical operation, as shown in Table 4. Fig. 4 shows the screen during a live session. It shows the set of elements that are available to users during their participation in a surgical operation. Up to four videos are available that are selected by the facilitator. The video quality can be configured by the administrator. On the right are the interactive and collaborative tools, such as chat, a whiteboard and an area for sharing files. Towards the top of the screen is a faded tool bar that appears when the cursor is moved. This tool bar can be used by the facilitator for various tasks, including ending a session and controlling access to other participants.

Fig. 4. Screenshot of a live operation. The main video is at the top of the screen. The two videos at the bottom of the screen come from an external camera in the operating room and a personal

3.2.4 Performance of the platform.

As a result of the tests with the configuration shown in Table 2, users perceived the videos and audio smoothly and the latency was less than one second, which was acceptable to the users located in the different facilities. The real value required by the FMIS was 50.5 Mbps, as shown in Fig. 5. Fig. 6 shows the screen of the test sesión with four live videos.

In tests carried out with the second situation, the system was left to dynamically establish the bandwidth needed to transmit uncompressed video signals to ensure a higher image quality. In this second situation, the videos from the codec equipment smoothly reproduced the video but the users' videos had missing frames, lacked synchronization between the audio and video, and involved a delay of up to 1.5 seconds. This was mainly due to the fact that the network architecture (nominal maximum rate of 100 Mbps) that was used for the test did not support the bandwidth required by the application. In response, the FMIS did not reduce the video image quality, but led to missing frames, which caused a lag between the audio and the video.

With respect to the server, FMS requires high RAM usage since it stores the cache of videos distributed on demand; if the requirements exceed the available RAM, the FMS is forced to use the hard disk cache which significantly reduces its performance. In the case of live videos, the cache size does not affect performance because they do not use it. On the other hand, when the sessions are recorded it is necessary to have sufficient space on the server's hard disk, which will vary depending on the quality you configure the videos with. One of the tests, 35 minutes long with four videos, resulted in one of good quality at 384x288 @ 30 fps with dynamic bandwidth, and the others with low resolution at 320x240 @ 30 fps and compression. A 2.6 GB was required (the good quality video took up 57.7% of the total); therefore it is vital to configure the video compression schemes and have large memory capacity in both hard drive and RAM for adequate reproduction of the sessions on demand.

The demands on the server's CPU were not critical in any of the tests, with a maximum of 35% for videos on demand and less than 8% for live video (with a server dedicated exclusively to this application). Fig. 7 shows the access page to the component Electronic Medical Records (EMR), this sesión contains the option to generate and/or consult the patient's historical clinical based on the standards followed by the Hospital Institution (IDU).

The "Authorized" role was created due to some facilitator surgeons prefer assigning other doctors the task of carrying out the initial interview with the patient, and later complete it themselves.

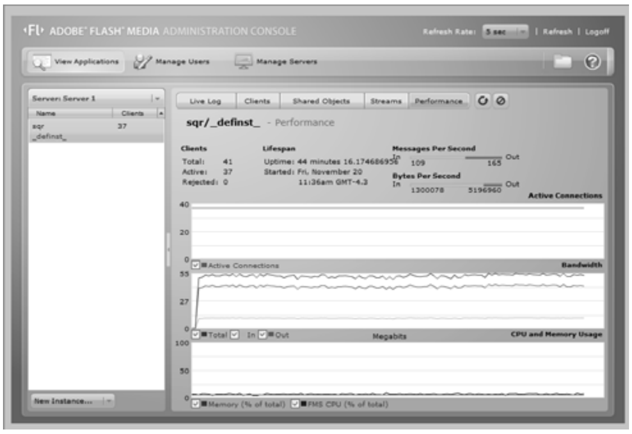

Fig. 5. Screenshot of the FMIS traffic monitor screen during the execution of one of the live tests.

The component Design of Online Assessments, allows the facilitator to generate evaluations for the group about the session with simple questions, fill in the blanks, simple or multiple selection or True or False, (or a combination of these), which can include segments of the previously edited videos or the EMR of the case (in order to secure the patient's confidentiality, the system does not show the user any identification information), or any other archive that the facilitator chooses to share which will further benefit the evaluation. In addition to all of this, the component Design of Online Assessments enables the selection of day and time for the evaluation as well as determining how long it will remain open. Fig. 8 shows a screen of this section.

Fig. 6. Display of the test session from different locations.

3.2.5 User Experience.

During preliminary testing with users of the RSS (in scenario 2), a group of three surgeons and four medical students used the system in various surgical sessions; personal interviews conducted observations were obtained as shown in Table 5.

In general, the RSS was well received, but the major objection was obtained in limiting use outside the University Campus or Internet2 networks to meet high requirement of the system (especially in countries such as Venezuela where speed of access to residential internet remains relatively low, the ISP that provides reaches just over 10 Mbps). Moreover, medical students had a more favorable perception of the RSS that urologists. As for the audio, the small delay of less than one second (0.5 sec overall.) in the beginning caused some discomfort to the users, but with the time and a little adaptation, they were able to follow along and the conversations between users and the facilitator in the operating room were flowing.

3.3 Discussion.

The development of this tool as part of the operational modules of RSS in a Web environment constitutes a step forward in the process of teaching surgical practice compared to traditional methods or even to slightly more advanced methods in which audiovisual and communication means are used.

Preliminary tests show an enthusiastic response from the medical staff that used the application, given the many benefits that the system offers and the user-friendliness of the application. Further field studies are required to assess other aspects (with greater participation of surgeons and students in the tests). This will enable the usability of the tool to be assessed.

Fig. 7. Screens of component Electronic Medical Records (EMR).

Fig. 8. Screens of component Design of online assessments.

Other limitations are linked to the digital divide in the environment in which the process is used. The technological elements cause limitations associated with the characteristics and the performance of the Network (bandwidth, jitter, latency and packet loss among other aspects). These elements can be critical, particularly in countries with a poor network infrastructure. In such cases, the quality of the videos needs to be significantly reduced which worsens the performance of the application.

One factor that has a considerable impact on operating performance is healthcare staff's expertise [36] in operating computers and system tools (and their willingness to use them).

Finally, the legal and ethical aspects that are involved in the process require careful study and analysis to cover the requirements of local and International law in this area [26]. To gather in a single tool the various functionalities that are usually located in three or four different applications, proved very attractive and highly valued by urologists and medical students, as they facilitate the development of different tasks in a transparent and comfortable manner.

Table 5. Summary of the observations in the interviews by 3 urologists medical users and 4 medical students during field trials (in the Facilitator and User modes).

Observations	urologists medical	Medical Student
Consider the quality of the videos as good or very good.	100%	100%
Considered acceptable audio delay.	67%	75%
Considered easy or very easy to setup and use of the RSS.	67%	100%
Considered very important to have in the RSS of the multipurpose application.	100%	100%
Consider to be willing to use the RSS for training.	67%	100%
Consider limiting the use of RSS only for network environments with large capacity.	100%	75%
Consider the forum as the least important component.	100%	75%
Consider video windows as the most important component.	100%	100%
Considered as satisfactory or very satisfactory experience with the RSS.	67%	100%

4 Conclusion

This development provides new opportunities for interaction in telemedicine, particularly in the areas of training and obtaining a second surgical opinion in a Web environment. The system is technically feasible with high potential for medical staff training which will result in better patient care requiring surgery. The RSS showed the technical feasibility of operating a Web platform environment with multiple high-performance components and integrated into a single application. Also, in preliminary field trials conducted, the application showed great potential and was well received by the medical teaching staff and the medical students that used the tool, however this should be evaluated in further work. The advantages of using the RIA were notable. It considerably facilitated the learning process in the practical experience of the students. The best results could be related, in part, to the decision to include Rich Internet Application (RIA) techniques. The high demand for bandwidth of the network represents a limitation, especially for users where high speed network services are not available.

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