Experiences with Arthron for Live Surgery Transmission in Brazilian Telemedicine University Network

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Abstract. The increasing network bandwidth capacity and the diminishing costs of related services have led to a rising number of applications in the field of Information and Communication Technology. A special case is applications based on video streaming. Telemedicine can be highlighted in some scenarios for applying this technology, such as clinical sessions, second medical opinion, interactive lessons or virtual conferences. These scenarios often imply a dedicated transmission environment. A restriction in such solutions is the inability to handle multiple video streams. Thus, this paper presents a low-cost infrastructure for video collaboration in healthcare and based on open technologies. The proposed infrastructure enables remote management of simultaneous multiple streams. We also discuss results of experiments held in the Lauro Wanderley Academic Hospital, Brazil. One of the results is the contribution for teaching experiences, particularly by allowing students to remotely regard surgical procedures and providing real-time interaction. Finally, we present new prospects for using the developed technology on other applications in Telemedicine and Telepresence.

Keywords: New Technology and its Usefulness, eHealth and Telemedicine Systems.

1 Introduction

The advances in Information and Communication Technologies (ICT) have been going through a notable transformation which is characterized by the global connectivity and the increasing use of multimedia devices. These factors have afforded the development of new transmission networks to handle large volumes of data and increasing power transmission [01], as the Internet2 [02]. High power transmission networks enable the development of applications that require a large bandwidth, as eHealth or Telemedicine applications.

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Telemedicine can be defined as the usage of information technologies and telecommunication systems to provide health support and medical attention when the distance separates the participants [03].

Telemedicine promotes the exchange of valid information for diagnosis, treatment of diseases and the continuous education of health professionals [04]. One scenario of telemedicine is videoconference, which allows real time integration between geographically distant sites by receiving and sending high quality audio and video. Telemedicine often involves transmission of sensible data, such as personal data, so that it is necessary to use security mechanisms that ensure the secure data transmission [05].

Actions directed to Telemedicine and eHealth is growing around the world at an accelerated pace. Large technology companies like Polycom [06], Tandberg [07] and Cisco [08] are investing heavily in these areas. Cisco, for example, presented in 2010, the Cisco HealthPresence, at the Healthcare Information and Management Systems Society (HIMSS) Conference. Cisco HealthPresence is a new technology in advanced Telemedicine that enables remote medical appointments, with features and technologies never used before. All of this combining high-definition video and high quality audio, as well as enabling medical data transmission, which gives the patient the feeling of being in a face-to-face appointment. According to Lima [09], among the several forms of Telemedicine there are videoconferences, which allow real-time integration, by sending and receiving high-quality video and audio along geographically distant points. Thus it is essential to ensure a secure data transmission.

In the surgical field, RUTE network can be used to mitigate the problems due to inequality in skilled health workforce distribution in Brazil [10] by implementing telementoring/teleconsultation programs for general surgery. However, to keep dedicated videoconferencing equipment into OR is not economically feasible, due it high cost. In addition, the standard equipment used by RUTE has only one video input with high definition (1,280×720) and two inputs with standard definition (720×480). In this sense, we present an infrastructure capable to manage and transmit live surgery multi-stream video in full high definition (1,920×1,080) that was developed to be used in the Brazilian telemedicine university network.

The management tasks are performed via web, as a service in the cloud, and the overall solution has a low cost. The software components of the infrastructure have open source licenses and the hardware components are based on standard PC (running Linux) and on off-the-shelf video capture devices and cameras. This infrastructure is an evolution of Arthron [11], [12], a tool designed to manage and transmit live media of distributed artistic performances.

In an effort to develop solutions to supporting Telemedicine activitites, many projects are underway. In this paper we discuss our experiences with Arthron for live surgery transmission in Brazilian Telemedicine University Network (RUTE). For three years we have been using Arthron for Telemedicine activities and testing the software solution and several formats of interaction, as discussed bellow.

2 Brazilian Telemedicine Network

The Brazilian Telehealth initiatives achieved their federal ministerial integration stage to establish a Telemedicine University Network called RUTE (in portuguese: *Rede*

Universitária de Telemedicina) [13]. This network is based on the implementation of telecommunication infra-structure in the University Hospitals, starting in January 2006 as is shown in Fig.01. After providing telecommunication infrastructure, The National Education and Research Network (RNP) [14], a Brazilian organization that promotes the development of technologies in the field of networks and innovative applications, is looking to build user communities to integrate Brazilian eHealth researh groups through RUTE network.

At this way, the "Video Collaboration in Health" Workgroup or GTAVCS (in portuguese: *Grupo de Trabalho Ambiente de Video Colaboração em Saúde*) is one initiative supported by RNP. GTAVCS [15] proposes an infrastructure based on hardware and software with remote management for capturing and securely distributing multiple simultaneous streams in order to provide support for several scenarios of video collaboration in health. As an obtained result of GTAVCS we also have Arthron [16], a software solution for media streaming management during telemedicine sessions. Arthron combines different software technologies to improve a virtual environment where Health professionals can share multimedia experiences, as surgery transmissions.

Fig. 1. Brazilian Telemedice University Network (RUTE). This shows a figure consisting of different types of RUTE memberships. Academical hospital, universities, presence points and telemedicine rooms. Currently RUTE connects 68 University Hospitals, will connect 80 across all federal states until 2015.

3 Arthron for Telemedicine

Initially Arthron was developed to address telematic dance perfomances requirements [01,17]. Since GTAVCS began in 2011, we are working hard to adapt Arthron to Telemedicine requirements [16,18]. So, Arthron has been applied effectively in the telemedicine domain. For example, currently it implements also a strategy of asymmetric/symmetric key cryptography methods to guarantee the confidentiality of the transmitted media. Despite this improvement, there were performance issues when applying data encryption in transmissions of multiple streams with different codifications. For solving that problem, a strategy of Video Reflectors was created. A reflector, as explained in [19], is an entity that receives a copy of a stream and then forwards multiple copies to other destinies (e.g. reflectors or streaming servers); in other words, the responsible for the video stream distribution is the network of the machine running the reflector.

The software architecture illustrated in Fig 2 shows the main Arthron software components: articulator, decoder, encoder, reflector, videoserver, videoroom and webservice. It also shows the possibilities for transmission rates: high quality (HD, SD) and low quality (mainly directed to the Web).

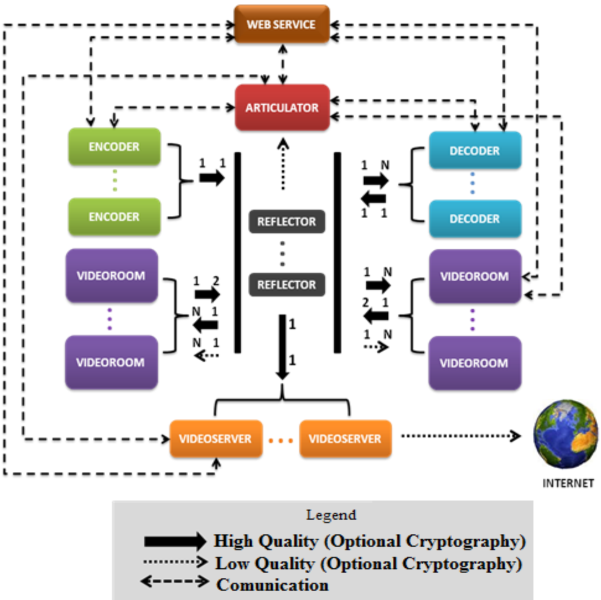

Fig. 2. Architecture overview. This shows a figure consisting of different types of lines. Elements of the figure described in the caption should be set in italics, in parentheses, as shown in this sample caption.

The **encoder** is responsible for making the media source encoding, which can be either a capture device or files stored in the hard disk – AVI, WMV or TS files. It is also responsible for streaming and sending the captured media to a reflector that will distribute the stream to the targets set by the articulator.

The **decoder** has the main feature of capturing a single media stream and decoding it in order to display the media on an appropriate device. The capture of the stream is done via a UDP port, which is automatically combined in advance with the articulator.

The **videoserver** has the core functionality of streaming low resolution video to the Web in various formats, specifically popular file formats used nowadays, such as FLV, OGG and H.264, allowing a wider range of options for users viewing the video streamed to the Internet. But to broadcast the media in different formats, it is required a robust machine that can perform the original audiovisual content transcoding.

The **videoroom** encloses the functionalities of encoder and decoder components, which makes easier the simultaneous communication with multiple clients. The development of this component had the main goal to meet an easier configuration of capture and display devices in a surgery room. Spaces such as surgery rooms are usually limited. Moreover, considering infectious disease control issues in a surgical environment it is advisable to concentrate on a single device the functions of capturing and displaying media.

The **webservice** main features are (a) create/update session, (b) create/update user, (c) insert or remove user from a session, (d) finalize a session. Sessions are composed of encoders, decoders and/or videorooms. In each session, you can isolate a specific configuration of components so that you can forbid access for unauthorized users to a particular audiovisual content. Thus, a single articulator is capable of manage various audiovisual sessions. This component meets requirement of easily manage multiple independent surgeries within the same hospital, for example. Thus, the content of each session (i.e. each surgery) is restricted to authorized users, who may be Medicine students, residents or doctors within the surgery room.

The **reflector** optimizes the distribution of media streams over the network. This component works in two different scenarios: one is the direct send of stream to a decoder or a videoroom, at the same rate it received; the other scenario is characterized by transcoding the media into a lower rate, in order to send it to the articulator.

The **articulator** is the principal and most complex component. It is responsible for remote managing all others components, enclosing much of the functionality offered by the tool. One of its main features is the scheduling of video streams, with which you can program the hour when media streams are sent from encoders to decoders.

4 Experiences of Using Arthron for Telemedicine

The development of Arthron for telemedicine used a multidisciplinary approach. The development team worked together with Health professionals to bring together the goals of each view. The first development cycle began using Arthron (v 1.0) for surgery transmission inside the Lauro Wanderley Academical Hospital of Federal University of Paraiba (UFPB). Using Arthron in practices, we could observe things that worked well and things that should be done. The use experience was very important to check requirements and to introduce new ones. We also have used Arthron for transmitting surgeries to other academic hospitals of RUTE as: São Paulo Academic Hospital, Center for Telemedicine and Telehealth of Federal University of Tocantins and Academic Hospital of the Federal University of Maranhão.

The surgeries transmission by Arthron had tested several setups according with technology and medical assets. By the way, it is one of the main advantages of Arthron comparing with another videoconference systems. Arthron deals with a variable number of media sources and offering a unique interface to manage them. This feature enables Arthron to cover several telemedicine scenarios as presented in what follows.

Scenario A is the most common scenario that we work in UFPB. This telemedicine scenario setup includes the surgery and the telemedicine rooms. Inside the surgery room we have the capture nodes (the cameras and microphones). Usually we work with two cameras: a mobile and an environmental one. But, we also can connect an endocamera used for laparoscopy procedures.

In this experiment, streams (audio and video) were transmitted between the surgery room, where the clinical procedure was performed, and the telemedicine room, where students and professors could interact and follow the procedure in real time. The procedure transmitted was an inguinal hernia surgery using laparoscopy. While a surgeon performed the surgery another doctor (the professor) followed the procedure with their students in the telemedicine room. The rooms were always connected by the surgeon and professor audios.

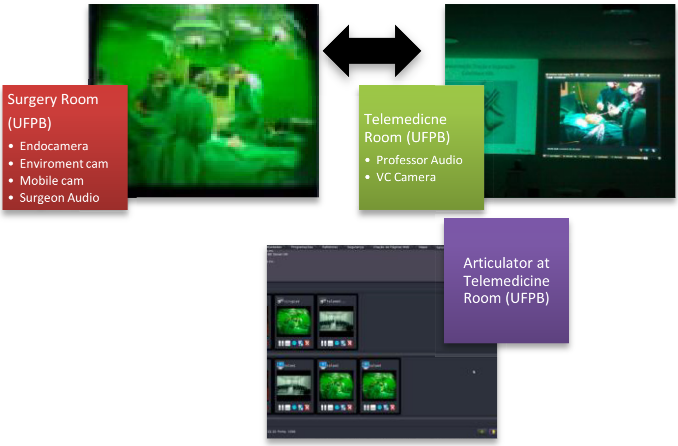

Fig. 3. Telemedicine **Scenario A**. Inside the Surgery Room, located in UFPB, we have the capture nodes. The Telemedicine Room used a VC cam to connected to Arthron. The both rooms were interacting by audio using Arthron. The Articulator illustrates a screenshot of Arthron for managing the multiple streams remotely.

Scenario B illustrates the distributed possibilities of using Arthron for telemedicine. The connected nodes could interact via audio or video when appropriate. In this experience we had four nodes. The main node was held in João Pessoa at the academical hospital Lauro Wanderley. Two cameras were used during the surgery transmission: the endocamera (internal view) and another mobile camera responsible to capture the external view. The surgery room and the UFPB telemedicine room sent and received streams, which allowed interaction among participants of the two rooms.

We also have remote participants using Tandberg VC Systems located in Tocantins and Sao Paulo. Multimedia streams were captured in the telemedicine rooms and displayed in the surgery room. These streams were switched according with participants' needs allowing to follow the surgery from different views.

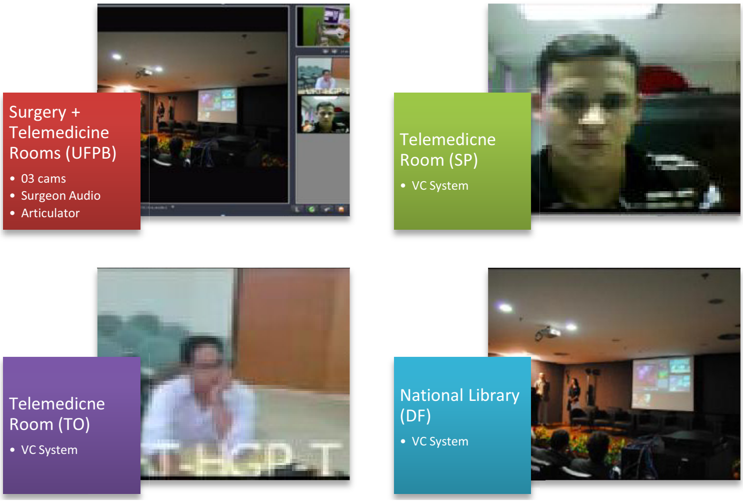

Fig. 4. Telemedicine **Scenario B**. The Surgery Room (UFPB) was the source node. The telemedicine room (UFPB) was the control node where we can observe and manage all the other nodes activities. The National Library (DF) and the two telemedicine rooms (TO and SP) used VC systems and also were integrated to Arthron as output nodes.

Fig.05 brings the scenario C that illustrates the adoption of innovative user interfaces for enriching the user experience using Arthron. An innovation of Arthron is to provide the possibility to manipulate 3D objects, especially human anatomical structures, while viewing other streams, such as video. The addition of these 3D models is especially useful as a didactic resource focused to distance training and learning. Through this feature the physician-teacher can show students in an integrated manner to live video, models that demonstrate the normal functioning of organs, tissues or structures of the human body. Furthermore, a user interace using Kinect was introduced. This feature makes easier the manipulation of the 3D models while viewing other streams managed by Arthron. In advance, not using hands to manipulate the computer during a telemedicine session prevent infection. Also, it enables the doctor inside the surgery room to manage some Arthron functions, as change a video stream or choose a 3D model to be presented.

In this work we use the natural interaction as a way to access the main control functions used for 3D manipulation [20]. For do that, we have to use tracking information defined by user hands, the primary and secondary hands. First it is necessary that the user use the mouse to choose the 3D model. After the user will see the initial screen where the user can choose a hand to begin waving to the Kinect, getting the tracking of both hands. The first hand tracked is responsible for handling the option chosen by the second hand. That is, if the user chooses with his second hand the "Zoom" button what will define how the object will approach or move away from the screen are the movements of approach or departure from first hand tracked, in relation to the Kinect.

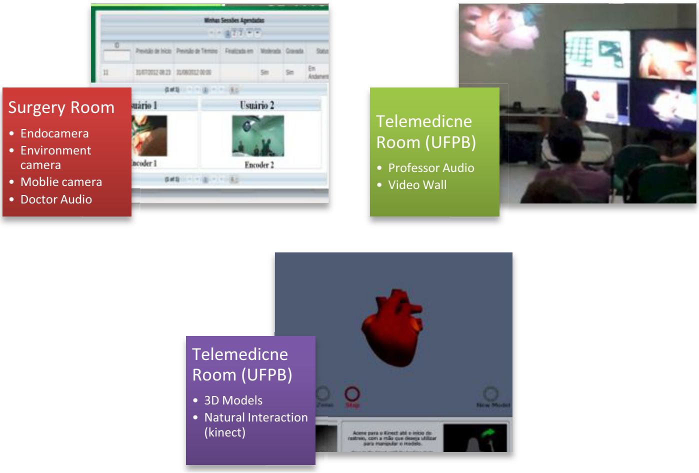

Fig. 5. Telemedicine **Scenario C**. This figure shows a illustration of the user interface of Arthron Web used to managed the streams. In the telemedice room we can see the students view of Arthron with the use of a cideo wall. We also can see a 3D model in detail, manipulated by natural interaction improved by Kinect.

In Fig.05 we also can observe other innovation for user experience: the video wall. The video wall is a set 42'' monitors used simultaneos to show the multiple streams transmitted by Arthron. So each video stream could be exhibited while the surgery is running. The students have also the whole views of the surgery in the same time and can choose which of them will be their focus.

5 Discussion

The most common solutions for telemedicine activities in Brazil are concerned in closed platforms [06,07,08]. In this work we presented a software based solution that included experiences for evaluating the effectiveness and acceptability of different technologies for providing telemedicne services. The predominant theme of these experiences is the use of digital technology to support live surgery transmissions. Live surgery transmission can be very useful as a teaching instrument, but also, as a research way to investigating new clinical procedures.

The review demonstrates that Brazilian Health iniciatives have been concerned with technologies platform and right now applications are the main goal. The sustainability of telemedicine projects has been also been a problem.

The implementation of telemedicine services could have a major impact on the organisation if Health professionals work together with the development team at the beginning. In this experience we have always the participation of Health professionals. There is thus a clear need for more well done telemedicine experiences.

Our experiences have demonstrated the feasibility of establishing systems using telecommunications technologies for live surgery transmissions. When considering the use of digital technologies, Health professionals must recognise that the use of telemedicine technologies may require some specific efforts as the use of communications functions and different modes of interaction. These issues need more telemedicine research study, mainly, multidisciplinary studies.

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