From Teletraining to Telehomecare – Design of Mobile and Multi-Stream Telehealth Systems

Pierre Lepage, Dominic Létourneau, Mathieu Hamel, Simon Brière, Michel Tousignant and François Michaud

Abstract—Telehealth success relies on the ability of information and communication technologies (ICT) to maximize the quality of care provided remotely, i.e., providing diagnostics and treatments of the same quality compared to face-to-face or conventional means, and maximize the benefits for the patients, the clinicians and the system of care. Because of the specific nature of health-related processes, successful development of telehealth technologies must be driven by clinical and application needs that are not addressed by currently available ICT. In this paper, we present two telehealth systems developed in two different contexts, one for telerehabilitation of surgical procedures, and one for teletraining of surgical procedures, and from which common requirements can be identified for the development of a more generic platform. This paper also situates where these systems are in relation to their stage of development and their assessment as telehealth technologies.

Index Terms—Teletraining, Telehomecare.

I. INTRODUCTION

TELEHEALTH is defined as the use of information and communication technologies (ICT) to extend health care service delivery across distance [6]. Recent advances in technology (e.g., digital imaging, mobile communications, wireless vital signs instrumentation) are enabling accelerated development of the field [6]. Telehealth revenues increased by 18% from 2011 to 2012, and are expected to grow rapidly and reach 1.8 million patients worldwide by 2017 [19]. Emerging evidence demonstrates the potential of telehealth systems to reduce unnecessary hospital admission, to decrease mortality rate [11], [14], to lower costs of care per patient [3], to increase satisfaction among users [7], and to deliver educational content to support patient self-care [13].

Home telehealth, or telehomecare, uses ICT to provide health care services into a patients home [6]. Remote vital signs monitoring is a common example and one promising market, with the use of personal health devices (e.g., pulse oximeters, blood pressure, scales) to monitor the vital signs of patients, to follow up on their recovery or to identify potential complications [6], [21]. The Beacon system from Health Interlink is one example of a system that does vital sign monitoring using Android tables, smartphones or laptops. A recent study conducted in Montreal reports significant benefits in reduction of hospitalizations, length of average hospital stay and emergency room visits [17]. AT&T, Qualcomm, Sprint and Verizon [21], along with Telus Health [18], are actively exploring opportunities in this area. The compound annual growth rate of this market is evaluated at 26.9% between 2011 and 2017 [25].

To conduct more lively and interactive consultations, virtual visits involve the use of video and audio for live and remote consultations between clinicians and with patients [6], [10]. This modality tries to emulate face-to-face assessments usually done by having either the patient go to the clinic or the clinician going to see the patient at home. Representing the telemedicine hype cycle into five phases (i. technology trigger; ii. peak of inflated expectations; iii. trough of disillusionment; iv. slope of enlightenment; v. plateau of productivity), real-time video visits (which we refer in this paper as tele-treatment) entered phase iii as of June 2010 [6], and is starting to show value. Many software video or web conferencing platforms are now available on the market, using computers and mobile computing devices. As real-time, high-bandwidth videoconferencing becomes pervasive in consumer technology and behaviour, it is expected that telehealth growth will accelerate and become a well-established channel for health service delivery and education [6].

To implement a tele-consultation system, the common strategy is to use a general-purpose telecommunication platform, either hardware (e.g., Polycom/Tandberg from Cisco) or software (e.g., Vidyo), designed for general videoconferencing. But videoconferencing is based on interaction in close proximity with a workstation, laptop or a mobile device (e.g., smart phones, iPad, RP Xpress from InTouch Health), providing one video stream and one audio stream. A mobile device makes it possible to provide interactions from different locations and of multiple perspectives in a home. However, clinicians have to indicate to the patients what they want to see, and patients need at least one hand to manipulate the mobile device. PTZ cameras on hardware videoconferencing codecs allow clinicians to control what is being observed, but only from a fixed location. Implementing a tele-consultation system on top of proprietary hardware/software codecs involves working with the providers to include additional features to the codecs (such as the addition of a data streams for vital signs transmission), or finding a workaround solution (e.g., the A-Vu Media system, validated at Winona Health in Minnesota, converts vital sign data as an image combined to the video stream). Consequently, any adaptation of the telecommunication platform to specific clinical needs (e.g., having multiple video streams from the same telecommunication station, sending vital sign data through a specific data stream, adapt audio communication to
specific contexts) may be difficult or impossible to accomplish depending on the priorities set by the providers.

Therefore, over the last decade, we have developed and validated original telehealth systems involving video, audio, specialized data transmissions and graphical interfaces. The approach taken involves real trials with clinicians and patients in the field, testing commercial and custom-made tele-consultation platforms, identifying and developing the technologies required to make them a reality, not simply technologically but as a practical modality in health practices. It is based on a holistic, bottom-up, iterative and incremental approach starting from small and simple systems addressing specific needs and current practices, in situ, and designed to minimize changes to the clinical practices, rather than to expect that clinicians and patients will adapt to the technology. In this paper, we present the characteristics of two telehealth systems, one for teletraining of surgical procedures and one for tele-treatment in home settings, outlining similar needs and specifications. We also outlines the upcoming steps in the development plan of the systems.

II. TELETRAINING OF SURGICAL PROCEDURES

Real-time teleconsultation with an emergency specialist offers significant benefits to patients in regions where no specialists are available and patients are frequently transferred to specialized centres [4], [12]. Significant reduction in medical assistance costs and in response time of professionals also resulted from teleconsultation in emergency medicine [4]. The practice of tele-emergency through videoconferencing is currently available for minor injuries [4]. Tachakra et al. [27] showed concordance above 95% in comparing teledicine with face-to-face consultations for trauma management of minor injuries, both in terms of diagnostic precision and quality of medical assistance. In the case of major injuries, preliminary studies indicate significant benefits of teledicine in both patient life support surveillance [26] [9] and patient management [31]. Preliminary results reported by Rogers et al. [23] [11] demonstrate that using two cameras was best suited for such application.

Therefore, the objective of our telehealth system is to provide assistance to local physician for training and while performing surgery procedures using proper kinesiologic gestural on unstable polytraumatized patients [15]. The system we developed consists of two independently controllable PTZ cameras, ceiling-mounted above a trauma stretcher. Each camera is installed at the end of a two degrees-of-freedom SCARA-type robot manipulator. Either one of the cameras is used to provide a global view while the other is focusing on the surgical intervention. Compared to a system which only extend a rotating arm [9], our design provides an infinite number of viewpoints, making it possible to better visualize interventions on various anatomical regions on the patient and to compensate for potential visual obstructions caused by members of the medical team performing their duties around the stretcher. Because standard pan-tilt-zoom (PTZ) videoconference cameras stack and execute the commands they received in a first-in first-out manner, a custom pan-tilt-zoom (PTZ) camera has been developed for fast and precise response to changes in positioning of the system. Otherwise, if the scene changes faster than the time required to position the cameras, the images provided by the system while it moves are not necessarily directed toward the region of interest. Real-time communication (audio, video) exists between the on-site emergency physician (through a wireless headset) and the remote expert (through the video streams of the two cameras synchronized and displayed on a split widescreen display). Assessment results are presented in [15].

Developed from 2004 to 2010, the technology was then transferred to Vigilent Telesystems inc., resulting in commercial product called MVu and available since Fall 2012. Figure 1 illustrates the system. For this technology, Medical Simulation Centers seem to be the most promising avenue for early adopters. We also developed algorithms to help decrease the operators cognitive load to direct its attention on the remote service to provide rather than on teleoperating the system. The user interface aims at improving functionalities of the initial interface by adding the following features: control of the point of view and region of interest directly on the video streams; automatic detection and repositioning of the point of view when visual obstruction is detected, and automatic tracking of specified areas while repositioning the point of view after obstruction has been detected. Results demonstrate that cognitive load can be minimized by controlling the cameras directly from the video feeds and by automating some of its positioning functionalities [28].

III. TELETREATMENT IN HOME SETTINGS

For such application, we started by conducting a first set of experiments by developing a tele-consultation platform that integrates a commercially available videoconferencing system (H323-Tandberg 550 MXP) with a touchscreen computer and external biosensors [29], [30]. The platform was developed to take into consideration the needs of different rehabilitation populations: orthopedics (Post Knee Arthroplasty), pulmonary (Chronic Obstructive Pulmonary Disease) and neurologic (post stroke condition speech therapy, post stroke balance and mobility improvement). The platform is driven by custom software called TERA3 that provides an overview of all the available patients, and eases the connection process by allowing the clinician to establish a connection with a simple double-click. The data collected during a session include the audio/video streams of the clinician and patient site,
data from external sensors (oximeter), network performances (bandwidth, jitter, packet loss), and results from a satisfaction survey (for the clinician only), all recorded in a local database. The platform was deployed through standard Internet Service Provider (ISP) (cable or asymmetric digital subscriber line), and the need to be able to use the cellular network has been identified, to reduce installation cost and time.

From these trials, some of the key issues identified are: 1) a tele-consultation system must be easy to use, for both the patients and the clinicians; 2) multiple video streams must be possible from the same telecommunication station; 3) transmission of audio and video streams must be possible from many locations in the home. General-purpose commercial telecommunication platforms are designed to have interlocutors remain close to fixed workstations, with one or two video stream per workstation, or use portable devices that have to be handheld with no optical zooming capabilities and no specific audio filtering to improve quality in reverberant environments. In home settings where a clinician may want to see the patient in different settings (kitchen, bathroom, bedroom, staircases), through a general view of the scene and/or a more specific view of a specific body part, the use of conventional telecommunication platforms becomes problematic, which consequently affects acceptability and usability.

We therefore decided to develop a mobile wireless PTZ camera, i.e., a battery-powered, wireless PTZ camera for mobile visual sensing in home settings. Figure 2 presents the device. A docking station allows the camera to be easily placed on top of a workstation or taken to another area. Other cameras (fixed or mobile) can also be connected to the workstation.

IV. DEVELOPMENT PLAN, CONCLUSION AND FUTURE WORK

Both of these telehealth technologies are at a stage where they have been tested in controlled conditions and have demonstrated to be robust enough to be tested in real life settings. According to DeChant et al. [8], this corresponds to Stage I (Technical Efficacy) and Stage II (Specific System Objectives). The next two stages would be Stage III (System Analysis – Assess global impact on access, quality and cost) and Stage IV (External Validity). However, to accomplish these stages, a complex interplay of barriers needs to be overcome to make that possible, barriers which may explain why telehealth has not yet been widely adopted in any country [22]:

- Acceptability: Poor ICT skills [5], [14]; Confidentiality concerns [2], [5], [11], [14]; Lack of awareness of the available technology and its potential benefits [1], [11], [14], [24].
- Technology issues: Usability problems [1]; Poor system stability and reliability [5], [14]; Limited access to broadband connections [11], [14]; Lack of interoperability between various telehealth solutions [1], [2], [13], [14].
- Organizational obstacles in the healthcare sector: Fragmentation within the healthcare sector [14], [20]; Lack of willingness to innovate [5], [11], [14]; Absence of service champions for promoting tele-healthcare services [5], [11].
- Absence of clear guidelines defining roles and responsibilities of stakeholders [5], [11], [14], [16]; Lack of technical quality standards [5], [11]; Unclear data protection legislation.
- Unclear evidence for return on investment [1], [11], [14]; Absence of reimbursement arrangements [1], [5], [20], [24].

For both systems, we are currently working on solutions to overcome these barriers, which necessarily take time and concerted effort. And even though both systems have distinct requirements that must be taken into consideration when designing new ICT for telehealth applications, there share common requirements, such as the flexibility of transmitting simultaneously multiple video, audio and data streams, and share also common challenges. This is why we are currently developing a common framework for both, because the technologies developed throughout these initiatives would greatly contribute to the design of an advanced and unique tele-consultation system, if they can be integrated efficiently. A first prototype is under development, and we are conducting trials with different components of the system, both with the private health telecommunication network and with general telecommunication service providers, to validate and influences the design choices.

ACKNOWLEDGMENT

This work is supported by the Research Chair in Terehabilitation of the Université de Sherbrooke, and the Fonds de recherche Québec Nature et Technologies (FRQNT) Strategic Network on Engineering Interactive Technologies for Rehabilitation (INTER).

REFERENCES


