Telehomecare Telecommunication Framework – From Remote Patient Monitoring to Video Visits and Robot Telepresence

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

Abstract— **Over the last few years, the number of remote patient monitoring (RPM) products and of videoconferencing systems has exploded. There is also a significant number of research initiatives addressing the use of service robots for assistance in daily living activities. From a technological standpoint, providing telehomecare services is certainly feasible. However, one technological barrier is to have access to a telecommunication platform that can be adapted to address the broad range of specifications and requirements of clinical and telehealth applications. Handling the full spectrum of possibilities requires a telecommunication framework that can transmit vital sign data from patients to clinicians, bidirectional audio-video from a standard computing device, and also multiple video streams and bidirectional transmission of control data. This paper presents a framework that integrates such capabilities. It also illustrates the versatility of the framework by presenting custom-designed devices allowing integration of capabilities ranging from RPM to video visits and robot telepresence.**

I. INTRODUCTION

Telehealth is defined as the use of information and communication technologies (ICT) to extend health care service delivery across distance [1]. Telehealth success relies on the ability of 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 to maximize the benefits for the patients, the clinicians and the system of care. Home telehealth, or telehomecare, uses ICT to provide health care services into a patient's home [1]. Services can be very diversified and include telecheckups (e.g., phone calls to ensure that the patient is doing well), telemonitoring by recording physiological data, teleconsultation, and teletreatment [2]–[4]. Teleconsultation and teletreatment require more lively and interactive virtual encounters. Referred to as tele-visits or video visits, these encounters use both video and audio, synchronized for remote, live consultations between patients, clinicians and caregivers [1]. Video visits are intended to become an alternative to traditional face-to-face assessments or treatments (usually done by either having the patient go to the clinic or the clinician visit the patient at home): when doing so, patient satisfaction is important in maintaining motivation and treatment compliance, and the satisfaction of healthcare professionals must be high in order for new treatments to become mainstream in clinics [5].

This paper presents the design our own telehealth integration framework, with capabilities ranging from RPM to video visits and robot telepresence, as presented in this paper. Section II gives an overview of telehomecare technologies, to explain why we are designing our own telehealth integration framework. Section III explains the design rationale and characteristics of our framework, illustrated in Section IV with a description of specific devices designed for telehomecare applications.

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II. OVERVIEW OF TELEHOMECARE TECHNOLOGIES

Technologies required to make telehomecare possible can be categorized as follows:

- **Remote Patient Monitoring (RPM)**. RPM basically allows a patient to use mobile ICT devices to measure vital signs and log/send the data to a healthcare professional [1], [6]. A multitude of solutions exist, from manual to automatic entry of the data in electronic medical records [7]. The Beacon system from Health Interlink is one example that does vital sign monitoring using Android tablets, smartphones or laptops. A recent study conducted in Montréal reports significant benefits in reduction of hospitalizations, length of average hospital stay and emergency room visits [8]. The compound annual growth rate of patient home monitoring market is evaluated at 26.9% between 2011 and 2017 [9], and a great number of companies are interested by this market, not only involved in health (e.g., Medtronics, GE Healthcare, Johnson & Johnson), but also in telecommunication (e.g., AT&T, Qualcomm, Sprint and Verizon [6], Telus Health [10]) and in home security (e.g., Honeywell Life Care). But the home healthcare sector is quite fragmented, making compatibility of devices and software a concern: there are vendors that manufacture peripherals, vendors that manufacture hubs and software that only support select brands of peripherals, and applications for managing data that are not compatible with other technologies [7].

- **Videoconference**. There is a high number of software videoconferencing or screen sharing products available, with platforms like Skype, Vidyo, Webex, GoToMeetings, just to name a few of the hundred[1] that exist. These products are based on close proximity interaction with a workstation, laptop or a mobile device (e.g., smart phones, tablets), providing bidirectional communication of one video stream and one audio stream. Also, even though a mobile device makes it possible to provide interactions from different locations and of multiple perspectives in a home, clinicians have to indicate to the patients what they want to see, and patients need at least one hand to manipulate the mobile device. Pan-tilt-zoom (PTZ) cameras on hardware videoconferencing codecs (e.g., Polycom, Tandberg) allow to control from a fixed location what is being observed, but using hardware codecs mean higher cost and more complex installation and operation processes.
- **Robot telepresence**. To provide complete mobility to sensors and exert a physical presence in the home, robot telepresence [11], [12] is a possible solution. InTouch Health has been offering its mobile robot RP-VITA to conduct virtual visits in hospitals, but at a cost of 4 k$ to 6 k$ per month [13] it may be too expensive for telehomecare. Lower cost platforms exist, such as VGo, QB [14], Giraff [15], beam+/Pro, Mantarobot and Double 2. They usually consist of a mobile base, a camera, proximity sensors, a screen and microphones, making them mobile videoconference systems, or more commonly referred to as "Skype on wheels" [16]. But still, the use of robot platforms in the home is mainly being addressed in research projects, providing services such as cognitive reminders, navigation aid, object manipulation and delivery, and more [17]–[22]. Only the GiraffPlus initiative focusses on combining mobile virtual visit capabilities with RPM, by having designed their own middleware for interfacing sensors [23]–[25].

These new technologies have the potential to improve patient outcomes and satisfaction, reduce the healthcare resources required to provide improved care, provide cost savings and more efficient use of healthcare resources, and reduce hospitalizations [7]. Unfortunately, there are significant barriers to implementation of telehealth [7], [26]–[30], including costs, technological incompatibility, privacy and security issues, usability, acceptability and education of healthcare personnel in use of the technologies. These barriers are intertwined, making adaptability of the technology a key element for success. More specifically, a telehomecare telecommunication system designed 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 stream for vital signs transmission, PTZ control, multi video feed streaming, etc.), or having to find a workaround solution. Consequently, any adaptation of the telecommunication platform to specific clinical needs may be difficult or impossible to accomplish depending on the priorities set by the providers. Designing our own platform gives us more flexibility to address the implementation barriers for telehealth.

[1] https://vsee.com/blog/telemedicine-platform-reviews/, https://vsee.com/blog/videoconference/.

TABLE I
TELEHEALTH PLATFORMS

Products	RPM	Video	Robot
Reacts	No	Peer-to-peer Multi-stream	No
InTouch Health	No	Cloud-based 1-stream PTZ	RP-Vita
A-Vu Media	Partial	Cloud-based (Vidyo) 1-stream PTZ	No
VSee	Yes	Peer-to-peer Multi-stream PTZ	No
Equinoxe	Yes	Cloud-based (Medeo) 1-stream	VGo

III. DESIGN RATIONALE AND CHARACTERISTICS

To integrate RPM with videoconferencing and robot telepresence, a telecommunication framework must provide bidirectional multipoint communication of audio streams, multi video feed streaming (e.g., general view of the scene and a close-up view of a region of interest; a navigation camera and a videoconference camera on a mobile robot) and data (e.g., vital signs, commands and states of a remote device) from the same telecommunication station. Table I presents characteristics of some telecommunication technologies used in health care. None provides the complete spectrum from RPM to multi video feed stream and robot control.

Our solution is designed from the ground-up to be a flexible, cloud-based, real-time and versatile framework, to provide simplicity, robustness, efficiency, usability, adaptability and optimizability to clinical and practical needs and requirements. It provides secure audio, video and data transfer over a high-speed internet connection using TLS encryption. It supports encoding and decoding using Speex audio codec and the standard H.264 video codec, multiple simultaneous participants with multiple simultaneous video streams from more than one camera per station, a wide variety of off-the-shelf network PTZ cameras, and real-time transmission of data from vital sign monitors. A datacenter with servers and databases support the cloud services, which constitute the central node of the system. The cloud server manages access to the database and routes audio, video and data to the different client nodes, and can be hosted in secured locations (e.g., health or certified centres, to comply with various regulations such as security and confidentiality requirements) or even in homes. All transmissions are encrypted and denominated to preserve confidentiality. Client nodes can be located in clinical sites or in patient's or caregiver's homes. For clinical sites, clinicians can create sessions with the patients, manage them and establish communication in

Fig. 1. User interface showing a multipoint, multi video feed and data streaming session.

an easy way. Patients can have a simpler interface, only having to press a button to accept or end a session. The system is designed to be modular, to facilitate maintenance, improvements and expansion. It can be used on desktop and laptop computers and mobile devices. Figure 1 illustrates a typical display between three users, with one having two video feeds from the same location, alsotransmitting oximeter and ECG data in real-time.

IV. Specific Devices for Telehomecare Applications

To illustrate the versatility of our framework, we also designed specific devices to address needs associated with telehomecare which would be difficult to integrate with existing products. General-purpose videoconferencing 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. During sessions in which patients have to move, such as during teletreatment [31]–[35], a more flexible setup on the patient side is required. Figure 2 presents the patient station designed. A touchscreen interface, a speaker with microphone and an Intel MiniPC NUC computer with SSD (placed behind the touchcreen interface) are installed on a tripod, and connected to a router. A battery-powered, wireless PTZ camera (located on a docking station on top of the touchscreen interface) was custom-designed to allow patients to change location of the camera as needed. For audio communication when the patient is far from the tripod, we also designed a mobile audio communication device. It is a small, lightweight, WiFi device with two microphones, one speaker and a small embedded microcontroller working as a stand-alone full-duplex communication device.

For more generic RPM monitoring, we also designed a bluetooth wireless gateway to interface with vital sign monitoring devices (e.g., ECG, blood pressure, scale, oximeter, glucometer), as shown by Fig. 3. The gateway acts as a client node, allowing wireless communication with the cloud services of the framework.

Finally, we are currently working on interfacing our system with IRL-1, an interactive robotic testbed platform

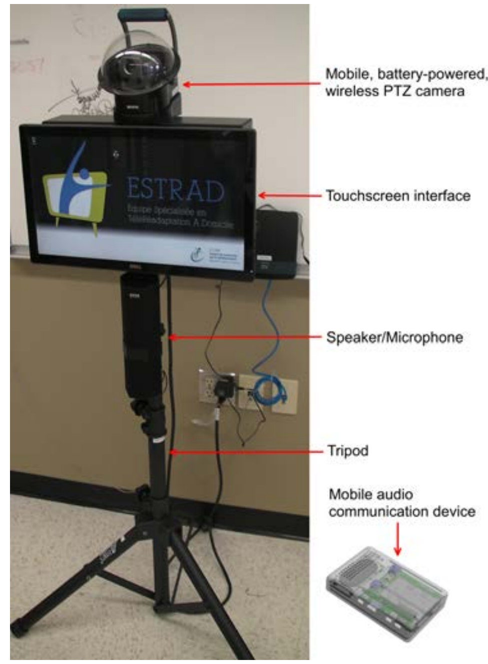

Fig. 2. Tripod station (left) and the mobile audio communication device (right) (dimensions: 80 mm × 50 mm × 18 mm).

Fig. 3. Wireless gateway for RPM.

shown in Fig. 4. Such a platform is the ultimate test for a telehomecare telecommunication framework, because the robot is equipped with a 8-microphone array, a panoramic camera, a Kinect sensor, a laser range finder, an expressive face, an orientable head, two compliant arms with four degrees of freedom (DOF) and grippers [36]. We plan to install a small tablet on its torso, and extend our previous work on home robot telepresence [37] and teleoperation interfaces [38] using our framework.

V. Conclusion

Until telehomecare becomes a widely adopted service, we need to have access to a telehomecare telecommunication framework to test and experiment different usages and applications. Our framework is currently used in clinical trials involving private health telecommunication network and general telecommunication service providers, to validate

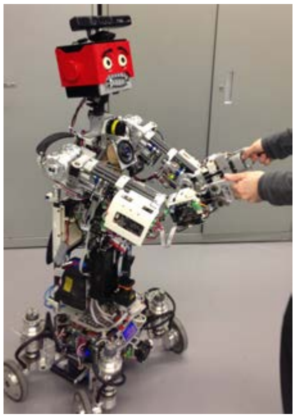

Fig. 4. The IRL-1 robot.

and influence the current design choices.

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