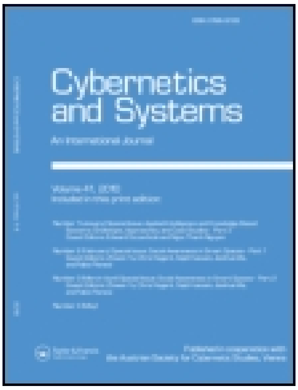
This article was downloaded by: [150.241.253.10]
On: 12 March 2014, At: 08:16
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Cybernetics and Systems: An International Journal
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ucbs20

Universal Remote Delivery of Rehabilitation: Validation with Seniors' Joint Rehabilitation Therapy

Gorka Epelde [a], Eduardo Carrasco [a], Shabs Rajasekharan [a], Jose Manuel Jimenez [b], Karmelo Vivanco [c], Isaac Gomez-Fraga [d], Xabier Valencia [d], Julian Florez [a] & Julio Abascal [e]

[a] Vicomtech-IK4, Donostia-San Sebastian, Spain
[b] STT Engineering and Systems, Donostia-San Sebastian, Spain
[c] Baleuko, Durango, Spain
[d] Hospital Donostia, Donostia-San Sebastian, Spain
[e] University of the Basque Country, Donostia-San Sebastián, Spain

Published online: 12 Mar 2014.

To cite this article: Gorka Epelde, Eduardo Carrasco, Shabs Rajasekharan, Jose Manuel Jimenez, Karmelo Vivanco, Isaac Gomez-Fraga, Xabier Valencia, Julian Florez & Julio Abascal (2014) Universal Remote Delivery of Rehabilitation: Validation with Seniors' Joint Rehabilitation Therapy, Cybernetics and Systems: An International Journal, 45:2, 109-122

To link to this article: http://dx.doi.org/10.1080/01969722.2014.874807

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing,

Cybernetics and Systems: An International Journal, 45:109–122
Copyright © 2014 Taylor & Francis Group, LLC
ISSN: 0196-9722 print/1087-6553 online
DOI: 10.1080/01969722.2014.874807

Universal Remote Delivery of Rehabilitation: Validation with Seniors' Joint Rehabilitation Therapy

GORKA EPELDE[1], EDUARDO CARRASCO[1], SHABS RAJASEKHARAN[1], JOSE MANUEL JIMENEZ[2], KARMELO VIVANCO[3], ISAAC GOMEZ-FRAGA[4], XABIER VALENCIA[4], JULIAN FLOREZ[1], and JULIO ABASCAL[5]
[1] *Vicomtech-IK4, Donostia–San Sebastian, Spain*
[2] *STT Engineering and Systems, Donostia–San Sebastian, Spain*
[3] *Baleuko, Durango, Spain*
[4] *Hospital Donostia, Donostia–San Sebastian, Spain*
[5] *University of the Basque Country, Donostia–San Sebastián, Spain*

Remote rehabilitation applications still have limited deployment. The path to achieve greater user acceptance and adherence lies in the provision of solutions in their real-life context. Such acceptance is gained through flexibility provided in terms of location, client device, interaction means, and content.

This article presents a universal remote rehabilitation delivery approach supporting the introduced flexibility needs. Furthermore, an implementation of the approach in joint rehabilitation for the elderly is described.

The approach has been evaluated in a real scenario within Donostia Hospital. The usability evaluation results show the validity of the approach and the acceptance of the developed human–computer interaction paradigm.

KEYWORDS Abstract user interfaces, inertial sensors, joint rehabilitation, seniors, telerehabilitation, universal access, universal remote console (URC), virtual humans

INTRODUCTION

It is undisputed that during the last few decades the use of user-centered design methodologies (International Organization for Standardization 2010) in service

---

Address correspondence to Gorka Epelde, Vicomtech–IK4 Research Centre, Mikeletegi Pasealekua 57, 20009 Donostia–San Sebastian, Spain. E–mail: gepelde@vicomtech.org

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/ucbs.

development has led to greater acceptation of the developed human–computer interaction (HCI) solutions and the services themselves.

Despite the achievements and advances in the user acceptance of technological products and services and their interaction, the shift toward multi-environment service consumption limits traditional systems' deployment (Burrell et al. 2000). From a design point of view, the main limitations of these services are (1) the limited consideration of the user's real-life context (e.g., not considering user's needs and preferences changes from a home scenario to a work scenario or to an on-the-go scenario) and (2) the lack of an architecture support to provide the required flexibility in terms of location, client device, interaction means, and content (Hong and Landay 2001).

One of the main application areas of these advanced services is the remote provision of health services. The number of people aged over 65 is projected to grow from an estimated 524 million in 2010 to nearly 1.5 billion in 2050 worldwide (World Health Organization 2011). This trend has a direct impact on the sustainability of health systems, in maintaining both public policies and the required budgets. As a result of these global trends and the need to provide individual attention, a tendency toward resource and patient care staff overload in hospitals is occurring and is especially true for rehabilitation, because it is generally characterized by repetitive encounters over a long time period with low intensity (Parmanto and Saptono 2009).

Parting from this motivation scenario, telerehabilitation is defined as the use of telecommunications to provide remote rehabilitation services (Brienza and McCue 2013). Brienza and McCue (2013) presented a study that defends the benefits of providing rehabilitation services in the natural environment (where patients live, work, and/or interact socially) rather than in the clinical setting. The aforementioned authors described a collection of studies reporting the benefits of rehabilitation service provisioning in the patient's own environment, in terms of increased functional outcome, enhanced patient satisfaction, reduction in needed therapy duration and cost, and pathology specific benefits.

One of the main beneficiaries of telerehabilitation, according to its challenges and market trends (Simpson 2013), is people with disabilities. The main challenges observed by the study are the high number of people with disabilities (increased by the society getting older), the diversity of needs and preferences of each person, and their economic limitations.

In order to answer the demand of a remote rehabilitation service that will adapt to the requirements and needs of these large and diverse user groups and their real-life usage contexts, it is necessary to define a universal remote rehabilitation delivery architecture (Winters 2013).

The objective of this article is to introduce an approach to support the universal remote rehabilitation delivery. Furthermore, the research also covers the implementation for validating the approach focused on seniors' knee replacement rehabilitation therapy. This implementation targets the increased treatment adherence through the use of realistic avatars as the human–computer interaction paradigm and the use of a portable high-definition tracking system for precise joint angle measurement and monitoring.

The article is arranged as follows: in the next section a survey of the current body of work related to present article's objectives is presented. Then, the proposed architecture approach is described. Next, the implementation for the validating of the approach is reported. Then, the evaluation methodology and the obtained results are presented. Finally, the conclusions and the future work are discussed.

STATE OF THE ART

In the following subsection, the evolution of the telerehabilitation architectures will be studied. Next, focusing on the implementation of the approach for elderly users, the most accurate HCI paradigms for seniors will be analyzed. Finally, joint rehabilitation assessment technologies will be revised.

Evolution of the Telerehabilitation Architectures

In general, telerehabilitation applications fall into two main categories. The first application type is called *real-time interactivity* application. Traditionally this application type has been achieved through videoconference means. The second type of application works using an asynchronous communication and is known as *store-and-forward* application. This application type stores the therapy and forwards it to the patient. Similarly, the therapy results are stored and forwarded to the therapist.

The evolution of real-time interactivity applications from analogue to digital technologies has enabled the implementation of applications such as the shared whiteboard. The evolution of store-and-forward applications includes simple communications such as e-mail, Web solutions using Java applet/ActiveX (Reinkensmeyer et al. 2002), and more conceptual evolution toward service-oriented architectures (Mougharbel et al. 2009). The evolution toward service-oriented architectures and future Internet architectures (Światek et al. 2012) opens new opportunities that will benefit from the potential highlights of cloud technologies.

Among telerehabilitation's main challenges, the provision of universal access is one of the most important ones (Simpson 2013). Feng and Winters (2007) have worked on the universality of telerehabilitation architectures. Their work is based on the universal remote console (URC) standard. This standard defines an abstract user interface layer called the *user interface socket* and allows the development of pluggable user interfaces for any type of user. Their approach has some limitations: the integration of new interaction device protocols is limited; it is not possible to deploy non-URC controllers; and solutions that access more than one service are not addressed.

Older Adult-Centered Interaction Technologies

Motivated by the point that television (TV) is present in most homes and watching TV is one of the activities that takes up most people's leisure time (Eurostat European Comission 2012), TV has been actively researched for service deployments, especially for older adults.

With the evolution of information and communications technologies (ICT) and their incremental adoption by seniors, applications targeting the elderly have been developed for the PC and more recently for the mobile devices. Regarding telerehabilitation, PC-based solutions were initially developed recently evolving to TV-based game consoles and to mobile terminals. European citizens' ICT usage (European Commission 2008) evidence the need for an architecture that supports users' real-life context and its multidevice usage nature.

With regards to the type of content used to instruct rehabilitation follow-up at home, usually it is limited to a set of instructions provided to the patient informally or through printed material.

Initial telerehabilitation developments focused on videoconference applications (Nakamura et al. 1999). Later, with the aim to increase patients' motivation and objectivize their evolution, research advanced to gaming rehabilitation. Gaming rehabilitation's natural evolution has been the use of game consoles (Deutsch et al. 2008). The next big step has been in virtual reality (VR). Development of VR environments and interactive technology has led to a variety of applications focused specifically in the areas of disability, therapy, health, and rehabilitation (Nap and Diaz-Orueta 2013).

Research on HCI for seniors centered on VR technology have shown that virtual humans ameliorate seniors interaction with machines (Ortiz et al. 2007), Within the health sector, virtual humans have been adapted to advice army members (Rizzo et al. 2010).

Rehabilitation Assessment

Traditionally, physical rehabilitation assessment has been based on assessment scales and manual tools such as the goniometer and the dynamometer. With the emergence of VR and gaming rehabilitation, a wide variety of robotic systems specifically targeted at rehabilitation have been developed and have confirmed their therapeutic benefits (Kwakkel et al. 2008). The elevated cost of such robot-based therapies makes them unachievable for home rehabilitation.

Hence, interface devices (computer mouse, joystick, force sensor, cyber glove) that were not designed with rehabilitation in mind have been tested as an alternative for interaction and navigation within VR-based rehabilitation. Johnson et al. (2007) reported the use of a conventional force-reflecting joystick, a modified joystick therapy platform, and a steering wheel platform with stroke subjects. In recent years, with evolution of the main game console controllers to wireless and gesture technologies including motion-sensing technologies, there has been an active research area testing the validity of these devices for rehabilitation (Deutsch et al. 2008).

In regards to the rehabilitation of joints, different technologies are used for position sensing (Zheng et al. 2005), movement analysis (Zhou and Hu 2004), and joint angle estimation. Zheng et al. (2005) identified non-vision-based inertial sensors as the best suitable technology for home rehabilitation, due to the information they can provide for clinical assessment, their small size, and their relatively low cost and easy interface with computers. Recently, affordable and easy-to-install vision systems, such as the Kinect, have been used for joint rehabilitation assessment. However, as research by Bo et al. (2011) has underlined, the Kinect presents irregular performance in nonstructured environments. These authors underlined that the inertial sensor can also suffer from data corruption and suggested that this could be fixed by complementing it with information from the Kinect or by integrating inertial sensors with magnetometers.

PROPOSED APPROACH

This section introduces the technology required and adopted in our approach to enable user interaction solutions exchangeability and personalization.

The URC Framework

The URC framework (International Organization for Standardization 2008) is a five-part international standard (ISO/IEC 24752) published in 2008. This standard specifies a user interface socket (UI socket) that enables decoupling the user interfaces (UIs) from the target device or services and works as an interaction point for pluggable user interfaces. The framework also specifies resource servers as repositories for any kind of user interface and resource necessary for interacting with appliances and services to be shared among the user community.

Furthermore, the universal control hub (UCH) overcomes the transition to a URC-enabled world by implementing a gateway-oriented architecture of the URC framework (Zimmermann and Vanderheiden 2007). The UCH connects both URC and non-URC compatible controllers and target devices/services bridging across multiple targets and target platforms and providing a choice of user interfaces for various controller platforms.

Universal Remote Rehabilitation Delivery Architecture

The architecture proposed in this article for universal remote rehabilitation delivery is made up of three layers: the user layer, the cloud layer, and the hospital layer. For an improved understanding, the proposed architecture is depicted in Figure 1.

The user layer defines a common approximation for the different service consumption contexts that users have to deal with in their real lives (e.g., home context, hospital context, or on the go). Each service consumption context client is composed of a UCH middleware, a tracking solution, and a user interface. The UCH enables UI personalization and easy upgrading through its UI plug-and-play feature. In addition, the definition of a common interface specification for the different tracking systems in the UCH enables the seamless exchange of the tracking systems. Following a UCH middleware-based architecture approach, the system can be easily extended with new services (e.g., health services, home control) in the future and user interfaces that span across several services or targets can be deployed.

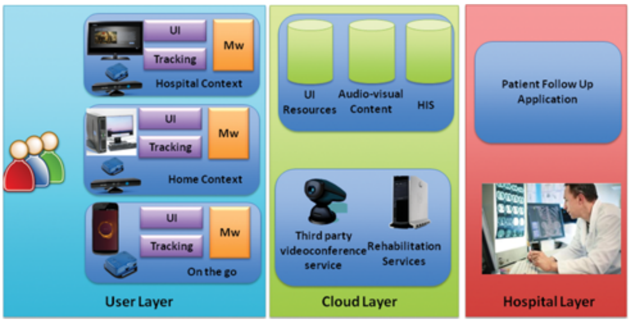


FIGURE 1 Proposed system architecture.

The cloud layer is responsible for ensuring the scalability of the services and it is composed of the following blocks: the UI resources repository and the audio-visual content repository, the rehabilitation services, and the hospital information system.

The UI repository follows the resource server concept introduced as part of the URC ecosystem (OpenURC Alliance 2013a) and implements the interface and guidelines provided by the OpenURC Alliance (OpenURC Alliance 2013b). This technology enables to incrementally support users with different needs and preferences and to upgrade UI elements or complete UIs based on users' capabilities and context evolution or maintenance tasks.

The developed audio-visual content repository supports different modalities, in order to meet all users' needs and preferences. Apart from a static repository, the most advanced scenario is targeting the fusion of the prescribed exercise content with the user's exercise tracking representation in the same audio-visual content.

The rehabilitation services can include basic to more complex services. The baseline services must include the support for therapy prescription and results assessment functionalities for the medical professional and the therapy load and results submission functionalities for the patient. These services can be extended to include other actors involved in the care cycle or provide new functionalities to the involved actors.

In order to provide open interfaces for third-party developments and make sure that the implementation is hospital information system independent, the rehabilitation services must be defined following Web Services Description Language specifications. The integration of videoconference can be provided as part of the rehabilitation services or externally as depicted in Figure 1.

The main element of the hospital layer is the follow-up application, which implements the medical professionals' client to access rehabilitation services. The functionalities to be implemented for such a client include rehabilitation therapy prescription and patient's therapy execution tracking results revision.

In summary, the inclusion of the UCH technology in the architecture approach enables the easy personalization of UIs, allows using URC and non-URC controller technologies (choice of client device), maximizes available interaction capabilities, and provides a platform for adding new services in the future.

The presented approach proposes an architecture for service provision in users' real-life contexts (starting rehabilitation at hospital, moving home, and providing the chance to continue outdoors or while on the go). Apart from the localization choice, the solution allows having different service functionalities in each UI, providing the required service functionalities per scenario.

IMPLEMENTATION

The implementation to validate the approach has been developed for knee replacement rehabilitation and more specifically for the postsurgical teletraining of body joints. The implementation has been focused on seniors, the user group suffering this pathology most.

On the service layer, the initial rehabilitation services implementation includes four web services: (WS1) rehabilitation therapy prescription, (WS2) load therapy exercises, (WS3) send exercise monitoring, and (WS4) load therapy monitoring and historical services.

The rehabilitation workflow is detailed in the following: First, the medical professional (medical doctor or therapist) prescribes a therapy through the WS1 service. Later, the patient loads the therapy and the assigned multimedia content using the WS2 service, realizes the exercises while being monitored, and the monitoring is updated to the cloud through the WS3 service. Finally, the rehabilitator loads the therapy monitoring for assessment using the WS4 service. Figure 2 shows a conceptual diagram of the developed web services.

Skype videoconferencing was selected as the third-party videoconference service and it has been integrated through SkypeKit API (Zivkov et al. 2012).

On the user layer, the following services have been integrated with the UCH middleware: (WS2) load therapy exercises and (WS3) send exercise monitoring. In addition, the inertial sensor-based tracking system and the required modules for the virtual human—based interaction technology have been integrated with the UCH.

On the hospital layer, a patient follow-up application has been implemented that has been integrated with (WS1) rehabilitation therapy prescription and (WS4) load therapy monitoring and historical services. The following subsections detail the UI concept developed for seniors and the selected tracking solution. The implementation

FIGURE 2 Conceptual diagram with the developed rehabilitation services.

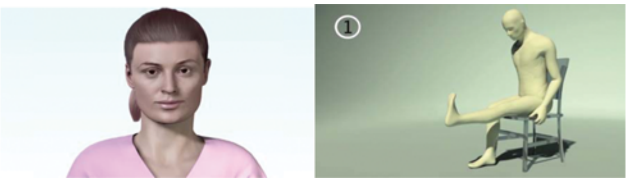


FIGURE 3 Virtual human—based rehabilitation therapy guidance.

of the cloud layer has been done on locally hosted servers, but porting to cloud service, such as the Amazon EC2, is planned to provide scalability and high availability and decrease system maintenance tasks.

Virtual Human—Guided Rehabilitation Therapy

A realistic virtual human deployed on TV was selected as the user interface interaction concept for the seniors' telerehabilitation therapy guidance. In order to achieve older adults' acceptance and have them follow a virtual therapist's instructions, a familiar and convincing look was specifically designed in collaboration with medical professionals. The voice of the virtual therapist was selected from a casting to meet the therapist profile in mind. For the dummy virtual human reproducing the exercises, a simple model was selected to avoid stigmatization. The developed virtual therapist and dummy concepts are shown in Figure 3.

Portable Inertial Sensors for Joint Angle Assessment

Precise joint angle measurement is required for specific rehabilitation therapy (elbow, shoulder, etc.) assessments. In addition to a precise and reliable solution, a home rehabilitation deployment should keep at the minimum the number of device technologies used, configuration needs, and costs. As suggested by the literature analysis, the approach's implementation has made use of a device that integrates the inertial sensors with magnetometers (STT Systems 2013). The selected solution provides precise orientations, angular velocities, and accelerations in real time and has been integrated with the UCH middleware through its Bluetooth connectivity and serial port profile implementation.

Information received from the inertial sensors is locally processed to calculate each flexion/extension angle for the selected biomechanical model. For the approach's implementation, left and right knee biomechanical models have been used. Then, the prescribed exercise repetition is assigned with the processed joint angle time—history data set and uploaded to the cloud using the defined rehabilitation service. Alarms per maximum/minimum joint angle flexion/extension can be defined currently to ease rehabilitation assessment by the therapist. Additionally, work is being carried out to identify underactivity and the recognition of evolution trends to suggest to the medical professional the need for a therapy/rehabilitation phase change.

EVALUATION

The developed system was evaluated with 13 medical professionals and 19 patients in the period January 2013 to July 2013. The recruited medical professionals' profiles were rehabilitation specific, evenly distributed between medical doctors and physiotherapists. Their experience was quite diverse, ranging from low (1—2 years), to medium (5—10 years), to high (20—30 years). With regards to patients, the sample was composed of 10 males and 9 females with an age range from 50 to 79 ($x = 69.31$; SD = 7.38), from the city of Donostia—San Sebastian (Spain), and its surroundings. The sample was composed of patients who had recently undergone knee replacement at Donostia Hospital. Only 15.79% had no formal education, 57.89% had completed primary education, and 26.32% had finished secondary education. Regarding the technology usage habits, 52.63% did not make use of connected devices, 21.05% used computers, 15.79% used tablets, and 26.32% reported having smart TVs but not making much use of their advanced features.

The technical setup on the patient side was composed of a TV set with the virtual therapist content as the HCI technology and with the inertial sensors for therapy execution monitoring. The sensors were identified with stickers numbered 1 and 2 and instructions with clarifying pictures were provided to the patient. For the therapist, patients' visual information was shown on a laptop, including a 3D representation of the exercise execution and 2D graphics of achieved joint angles in time.

For the therapists, a special meeting was arranged where the system was introduced. Therapists were then invited to a room where a prototype of the client was presented to them. Next they were asked to complete a usability questionnaire. Additionally, focus groups were set up to collect more information and detect improvement areas. For the patients, the technical setup was similar, but the system was tested by the patients and the monitoring results were reviewed by a therapist. The evaluation was explained to them by the therapist and they were administered a consent form for acceptance to participate in the evaluation session. Afterwards, sociodemographical data was captured and they were allowed to practice using the system. After the patients completed four therapy sessions, programmed for different days, they were asked to complete a usability questionnaire for the designed audiovisual content paradigm and look, tracking system, and acceptance of the developed system.

RESULTS

Medical professionals were very positive regarding the virtual therapist for therapy guidance though the simplicity of the dummy virtual human presenting the exercises was found to be a possible limiting factor for engaging with patients. One of the main comments from the virtual therapist was why recordings of real people could not be used instead of the virtual therapist. Some of the professionals also stated that the virtual therapist looked too serious and lacked empathy with the patient. Regarding the dummy virtual human, they thought that it should reflect the user's effort and

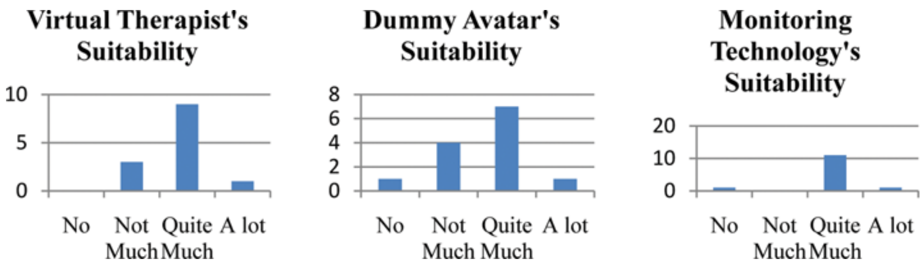


FIGURE 4 Graphical representation of the medical professionals' answers to questions regarding the solution's suitability.

pain, it should be dressed, and it should highlight the areas used in each exercise. Regarding the inertial sensors, they were identified as providing precise information but therapists were afraid that senior patients might not being able to put them on correctly. In general, the therapists conceived the solution as a valid, motivating, and complementary tool for outpatient rehabilitation at clinical facilities. Figure 4 presents therapist results regarding the solution's suitability.

Patients showed good acceptance of both evaluated virtual humans (therapist, dummy). The virtual therapist's design acceptance was confirmed with comments including patients considering it a serious and adequate character or patients requesting for more exercises. Concerning the dummy virtual human, patients expressed that it was easy to follow, but it was considered too simple to engage with. Regarding the inertial sensors, the patients had almost no problem in wearing them following the instructions provided. Figure 5 presents patient results regarding the solution's suitability and the perceived ease of putting the sensors on.

Concerning the marketability of the product (attitude toward product consumption), the therapists clearly understood the evaluated system as complementary and noted its potential to improve patient progress. Additionally, the patients reported that this system could improve their motivation to exercise. Figure 6 presents results related to marketability of the product.

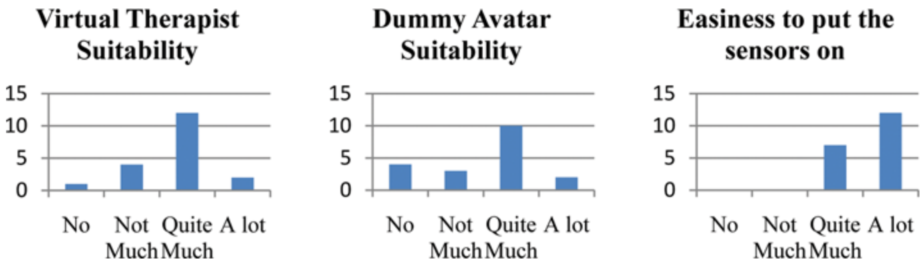


FIGURE 5 Graphical representation of the patients' answers to questions related to the solution's suitability.

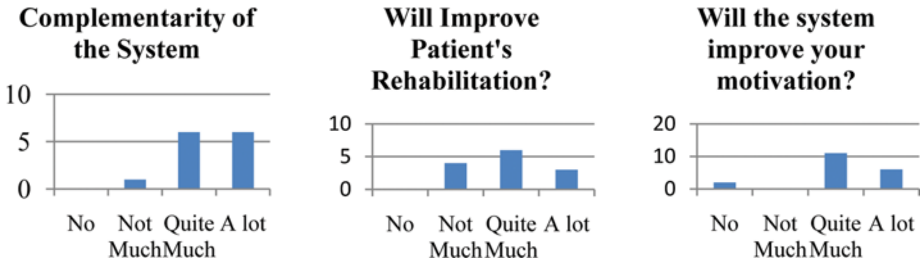


FIGURE 6 Product's complementarity and expected progress improvement compared to traditional therapy from professionals' perspective (left, middle). Patients' view on motivation improvement using this product (right).

CONCLUSIONS

This article has presented an architectural proposal, an implementation to validate such a proposal, and the corresponding evaluation results of a universal remote rehabilitation delivery system that considers the user's real-life context. For the patients' client controllers a UCH middleware (i.e., gateway oriented architecture implementation of the ISO/IEC 24752 URC standard) was used. Following this approach, limitations of previous URC-based rehabilitation works were overcome. The presented approach enables the use of URC and non-URC controller technologies, enabling the exchange of interaction and monitoring devices for rehabilitation and providing a platform for deploying new services in the future.

Furthermore, the provision of the rehabilitation services through standardized Web interfaces enables deployment with different hospital information systems without changing the rest of the implementation. Open standard-based Web service interfaces additionally enable third-party developers to easily develop new solutions/modules. Moreover, migration from the locally hosted server to cloud-based services ensures scalability and high availability and decreases system maintenance tasks.

The implementation for validation of the proposed architecture approach was developed on the older adults' joint rehabilitation therapy. Following state-of-the-art research results, a TV-based virtual human has been selected for rehabilitation therapy guidance for seniors. A high-fidelity virtual therapist (visual model and voice) and a dummy avatar reproducing the prescribed exercises were defined and developed in tight collaboration with therapists. Concerning the therapy progress assessment, the literature review on tracking devices for precisely measuring joint angles revealed two main options from which integration of magnetometers with inertial sensors was selected because they require the fewest devices and configuration needs as well as low home rehabilitation system costs.

Both medical professionals and patients positively rated the approach's implementation. Patient acceptance of the implementation for validating the approach confirms the proposed architecture and its implementation. Enhancements were requested with regards to the dummy virtual human reproducing the exercises, whose simplicity was identified as a possible limiting factor in patient engagement. Some therapists also requested that the expression of the virtual therapist should be relaxed in order to improve its empathy with the patient. Evaluation has shown that the patients had no problem with putting the inertial sensors on using the instructions provided.

FUTURE WORK

Responding to the evaluation results, the personalization of the dummy virtual human to the patient and exercise is being researched to increase patient identification with the virtual human in order to increase the targeted engagement. Furthermore, audiovisual content and automatic placement detection are being developed to guide seniors in the correct placement of the sensors. The authors' research is oriented toward the adaptation of the developed virtual reality concepts to the patients' needs, preferences, and therapy progress.

Regarding the proposed approach, the objective is to implement additional services starting from AAL (Ambient Assisted Living) and telehealth services. Self-management of chronic conditions is another application area where telerehabilitation has the potential to exceed that of traditional care and management strategies. Concurrently, security and performance implementations are being implemented to prepare the system for real-world deployment. Concerning research on the architecture approach, the aim is to move service integration to the Web service side through the upcoming ISO/IEC 24752—Part 6. This upcoming standard defines URC-enriched Web services through naming convention. Implementation of this part will require simpler middleware implementations, therefore benefiting resource-constrained device deployments.

Last but not least, in order to take into account the patient's real-life context, a methodology is needed in order to define which functionalities of the service will be implemented in each potential scenario.

FUNDING

This work was partially funded by the Basque Government ETORGAI 2011 Programme (eRehab). The authors of this article acknowledge the collaboration of Bilbomática, Ikusi, Vilau, Teccon, BioDonostia, and Osatek in the eRehab project.

REFERENCES

Bo, A. P. L., M. Hayashibe, and P. Poignet. "Joint Angle Estimation in Rehabilitation with Inertial Sensors and Its Integration with Kinect." In *Engineering in Medicine and Biology Society Annual International Conference*, edited by N. Lovell, 3479–83. Boston: IEEE, 2011.

Brienza, D. M. and M. McCue. "Introduction to Telerehabilitation." In *Telerehabilitation*, edited by S. Kumar and E. R. Cohn, 1–11. London: Springer-Verlag, 2013.

Burrell, J., P. Treadwell, and G. K. Gay. "Designing for Context: Usability in a Ubiquitous Environment." In *Proceedings of the 2000 Conference on Universal Usability*, edited by J. Thomas, 80–84. New York: ACM, 2000.

Deutsch, J. E., M. Borbely, J. Filler, K. Huhn, and P. Guarrera-Bowlby. "Use of a Low-Cost, Commercially Available Gaming Console (Wii) for Rehabilitation of an Adolescent with Cerebral Palsy." *Physical Therapy* 88, no. 10 (2008): 1196–207.

European Commission. *Seniorwatch 2—Assessment of the Senior Market for ICT Progress and Developments*. Brussels, Belgium: European Commission, 2008.

Eurostat European Commission. *Standard EuroBarometer 78—Media Use in the European Union*. Brussels, Belgium: European Commission, 2012.

Feng, X. and J. M. Winters. "An Interactive Framework for Personalized Computer-Assisted Neurorehabilitation." *IEEE Transactions on Information Technology in Biomedicine* 11, no. 5 (2007): 518–26.

Hong, J. I. and J. A. Landay. "An Infrastructure Approach to Context-Aware Computing." *Human–Computer Interaction* 16, no. 2 (2001): 287–303.

International Organization for Standardization. *ISO/IEC 24752:2008—Information Technology—User Interfaces—Universal Remote Console (5 Parts)*. Geneva, Switzerland: International Organization for Standardization, 2008.

International Organization for Standardization. *ISO 9241-210:2010 Ergonomics of Human–System Interaction—Part 210: Human-Centred Design for Interactive Systems*. Geneva, Switzerland: International Organization for Standardization, 2010.

Johnson, M., X. Feng, L. Johnson, and J. Winters. "Potential of a Suite of Robot/Computer-Assisted Motivating Systems for Personalized, Home-Based, Stroke Rehabilitation." *Journal of NeuroEngineering and Rehabilitation* 4, no. 6 (2007): 1–17.

Kwakkel, G., B. J. Kollen, and H. I. Krebs. "Effects of Robot-Assisted Therapy on Upper Limb Recovery after Stroke: A Systematic Review." *Neurorehabilitation and Neural Repair* 22, no. 2 (2008): 111–21.

Mougharbel, I., N. Miskawi, and A. Abdallah. "Towards a Service Oriented Architecture (SOA) for Tele-Rehabilitation." In *Ambient Assistive Health and Wellness Management in the Heart of the City*, vol. 5597, edited by M. Mokhtari, I. Khalil, J. Bauchet, D. Zhang, and C. Nugent, 253–56. Berlin: Springer-Verlag, 2009.

Nakamura, K., T. Takano, and C. Akao. "The Effectiveness of Videophones in Home Healthcare for the Elderly." *Medical Care* 37, no. 2 (1999): 117–25.

Nap, H. H. and U. Diaz-Orueta. "Rehabilitation Gaming." In *Serious Games for Healthcare: Applications and Implications*, edited by S. Arnab, I. Dunwell, and K. Debattista, 50–75. New York: IGI Global, 2013.

OpenURC Alliance. 2013a. "Resource Server HTTP Interface 1.0." Available at: http://openurc.org/TR/res-serv-http1.0/ (accessed September 27, 2013).

OpenURC Alliance. 2013b. "URC Technical Primer 1.0." Available at: http://openurc.org/TR/urc-tech-primer1.0/ (accessed September 27, 2013).

Ortiz, A., M. P. Carretero, D. Oyarzun, J. J. Yanguas, C. Buiza, M. F. Gonzalez, and I. Etxeberria. "Elderly Users in Ambient Intelligence: Does an Avatar Improve the Interaction?" In *Proceedings of the 9th Conference on User Interfaces for All*, edited by C. Stephanidis and M. Pieper, 99–114. Berlin: Springer-Verlag, 2007.

Parmanto, B. and A. Saptono. "Telerehabilitation: State-of-the-Art from an Informatics Perspective." *International Journal of TeleRehabilitation* 1, no. 1 (2009): 73–84.

Reinkensmeyer, D. J., C. T. Pang, J. A. Nessler, and C. C. Painter. "Web-Based Telerehabilitation for the Upper Extremity after Stroke." *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 10, no. 2 (2002): 102–8.

Rizzo, A. A., B. S. Lange, J. G. Buckwalter, E. Forbell, J. Kim, K. Sagae, J. Williams, B. O. Rothbaum, J. Difede, G. Reger, T. Parsons, P. Kenny. "SimCoach: An Intelligent Virtual Human System for Providing Healthcare Information and Support." In *Proceedings of the 8th International Conference on Disability, Virtual Reality and Associated Technologies,* edited by P. Sharkey and J. Sánchez, 213–21. Viña del Mar/Valparaiso, Chile: The University of Reading, 2010.

Simpson, J. "Challenges and Trends Driving Telerehabilitation." In *Telerehabilitation*, edited by S. Kumar and E. R. Cohn, 13–27. London: Springer-Verlag, 2013.

STT Systems. 2013. "IBS Sensor." Available at: http://www.stt.es/en/products/inertial-sensor/ibs-sensor/hardware/ (accessed September 27, 2013).

Światek, P., K. Juszczyszyn, K. Brzostowski, J. Drapala, and A. Grzech. "Supporting Content, Context and User Awareness in Future Internet Applications." In *The Future Internet*, vol. 7281, edited by F. Álvarez, F. Cleary, P. Daras, et al., 154–65. Berlin: Springer, 2012.

Winters, J. M. "Telerehabilitation Interface Strategies for Enhancing Access to Health Services for Persons with Diverse Abilities and Preferences." In *Telerehabilitation*, edited by S. Kumar and E. R. Cohn, 55–78. London: Springer-Verlag, 2013.

World Health Organization. *Global Health and Aging*. Geneva, Switzerland: World Health Organization, 2011.

Zheng, H., N. Black, and N. Harris. "Position-Sensing Technologies for Movement Analysis in Stroke Rehabilitation." *Medical and Biological Engineering and Computing* 43, no. 4 (2005): 413–20.

Zhou, H. and H. Hu. *A Survey Human Movement Tracking and a Research Proposal*. Technical Report CSM-420. Colchester, UK: Department of Computer Sciences, University of Essex, 2004.

Zimmermann, G. and G. Vanderheiden. "The Universal Control Hub: An Open Platform for Remote User Interfaces in the Digital Home." In *Human–Computer Interaction*, vol. 4551, edited by J. A. Jacko, 1040–49. Berlin: Springer, 2007.

Zivkov, D., M. Davidovic, M. Vidovic, N. Zmukic, and A. Andelkovic. "Integration of Skype Client and Performance Analysts on Television Platform." In *Proceedings of the 35th International Convention MIPRO*, edited by P. Biljanovic, Z. Butkovic, K. Skala, et al., 479–82. Opatija, Croatia: IEEE, 2012.