Title: Asymmetric Remote Collaboration for Physical Therapy and Implications on Rehabilitation/Movement Guidance

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Context

Physical rehabilitation is of utmost importance for people who suffered any type of injury that requires repetitive guided exercises, normally done in the context of a clinic or hospital, with specialised staff and may or may not require special equipment. Previous work showed that to aid the process of rehabilitation it is possible to add individualised unassisted sessions as a complement to the part of the rehabilitation process by giving automated feedback, so the users can perform the exercises in the comfort of their homes [1-4]. This is possible by using Extended Reality technology (XR), that enables the tracking of the users movements, which are then used to give them feedback about their exercise using Head-Mounted Displays or augmented floors.

SleeveAR, for example, uses custom bidimensional widgets and a sleeve that enable instant feedback about the correctness of the movement being performed, and uses a gamified approach by giving a score in the end [1]. This approach is promising, but these systems only give feedback about the exercise being performed, and do not suggest improvements for it, which may cause additional lesions in the patients and contribute negatively to the rehabilitation process. In this case, we acknowledge that the use of automated systems is not enough and individualised feedback may be needed. Also, we acknowledge that in some more specific cases, going to a rehabilitation clinic may not be always feasible due to the limited mobility of patients, and enabling individualised rehabilitation at their home or care facility would facilitate the rehabilitation process. The use of XR technology can be used to **enable collaboration between therapist and patient**, even remotely, in order to provide individualised feedback and guidance throughout the whole process. Previous works in rehabilitation are still limited to single-user utilization [1][2][3], and leaves unexplored the remote rehabilitation scenario, where a remote therapist could remotely guide the patient to perform the rehabilitation process.

Preliminary work from Crowe et al.[6], shows that in the rehabilitation process it's extremely important for the therapist to establish rapport with the patient, so that he can provide guidance using verbal and non-verbal cues. In that regard, a successful guidance system should enable effective communication between both parties to enable effective collaboration, communication and coordination between both therapist and patient. Even though previous works have tackled remote collaboration in different areas of expertise, such as medicine and architecture [4][5], the area of physiotherapy has its own peculiarities as the focus is on the body of the patient, and not on the virtual environment itself. Because of that, it is not yet clear how users should be represented (either in Virtual Reality or Augmented Reality or a mixture of both), how the feedback should be given to the patient, what type of modality (e.g. video, audio, tactile) should be used for interaction and feedback[7][8]. Haptic feedback for sure, could be used to both provide specialised feedback, but also for the user to indicate where the lesion is prevalent [7]. Remote rehabilitation can also enhance classic in-person rehabilitation by enabling communication between both parties while also giving real-time feedback to both users about the exercise, which can be used by the instructor to suggest how it can be improved. In such a collaborative scenario, it is not only important for the therapist to be a passive observer of the patient, but it is also important to communicate effectively with them, to solve issues with one exercise or the treatment as a whole.It is also still not clear, the role that remote rehabilitation can have in the

rehabilitation process as a whole, if it can be used as a complement to the normal rehabilitation process and to what extent it can replace classical in-person physiotherapy.

The primary objective of this research is to delve into the possibilities of **enabling remote asymmetrical collaboration for rehabilitation** by examining how to properly offer guidance for both therapists and patients, and explore how these should be represented, how the feedback should be given and perceived, and to what extent remote rehabilitation can substitute the in-person rehabilitation process. We aim to work together with real physiotherapists and patients as part of the process to provide guidelines on the use of XR for remote rehabilitation movement guidance. The project is aligned with the PC1 as it is involves collaboration between user in an asymmetrical context, with one user being fully immersed in VR being the physiotherapist and a patient, which can use his full body to interact with Augmented Reality and receive real-time feedback.

About the Research teams involved

Research activities will be conducted in the DIVA (Design, Interaction, Visualisation & Applications) group of the Computer Science & Networking department at Télécom Paris, Institut Polytechnique de Paris. The group research activities focus on novel interaction techniques (particularly with respect to large and small-scale devices), VR/AR/XR, information visualisation, digital fabrication & design, and new technologies for teaching. This thesis will be mainly supervised by professors Eric Lécolinet and Daniel Pires de Sá Medeiros, which are specialist in the fields of Haptic Devices and Virtual and Augmented Reality (VR/AR) applied to Human-Computer Interaction (HCI).

The work will also be supervised by Prof. Marcos Serrano the University of Toulouse within the Elipse research group on the IRIT Lab, which specializes in the design of novel interaction techniques in the field of ubiquitous computing. Additionally, we may involve researchers in Université Paris Saclay to get clinical validation of the methods proposed during the period of the thesis.

Motivation and Thesis Objectives

The main goal of this thesis is to explore remote collaboration for physical rehabilitation where the therapist is transported into the patient space, using a mixture of Virtual and Augmented Reality technologies. To that extent, we will delve into how the users should be represented in such a system, and also how the interaction should be done. We aim to explore different input and output modalities such as visual [1,2,3] and haptical [7,8] to enable collaboration and give feedback to both users. These questions will be evaluated through prototypes and user studies, and for the evaluation we aim to use real users. For that, we aim to rely on establishing partnerships with rehabilitation clinics to test our proposed systems with real users.

The results of the research conducted will be submitted in major venues in the HCI and VR domain in conferences such as ACM CHI, IEEE Virtual Reality and ISMAR (Core A*) and top journals in the field such as IEEE Transactions on Visualizations and Computer Graphics and is part of the priority themes of PC1 of PEPR Ensemble.

Year 1

In this phase the student will perform a thorough related work review and establish partnership with physical therapy clinics. In this period, they will also build the initial prototype that enables collaboration between both one therapist and one patient.

Year 2

After that the student will start exploring different forms of representation and feedback which will be evaluated through user studies.

Year 3

Representations and user interaction using visual and haptic feedback.

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