Collaborative serious gaming in augmented reality for motor function assessment

Project proposal for eNTERFACE'16

Marina Cidota and Stephan Lukosch

Faculty of Technology, Policy and Management, TU Delft, The Netherlands

February, 2016

Abstract

TU Delft and Leiden University Medical Center joined in the Technology in Motion (TIM) research project (for more, visit https://tim.lumc.nl/site/en/home/) to investigate the potential of the novel Augmented Reality (AR) technology to improve the assessment of motion disorders for different patient groups. Various diseases affect human motion (e.g. neurovascular diseases, neurodegenerative diseases, and musculoskeletal pain conditions). Currently, each medical discipline uses disease-specific clinical tests to assess motor (dys)function, based on subjectively scored and low-resolution clinimetric tests, qualitative video analysis, or cumbersome marker-based motion capturing. As such, no standard protocols for motion recording exist with respect to type of movements and activities of the upper extremity in various patient groups. For a better understanding of how different disorders affect motor function, a uniform, standardized and objective evaluation is a desirable goal in the study of motion disorders.

In this project, our aim is to design and implement a collaborative game for arm/hand motor function assessment. For this purpose, we want to combine AR with serious gaming and automatic tracking of the hand and body to facilitate unobtrusive, cost-effective and patient-friendly methods for objective evaluation of upper extremity motor dysfunction. The game should also allow the therapist to interact and collaborate with the patient during the assessment as well as adapting the game to the patient's physical capabilities.

1. Project objectives

The project's goal is to design and implement a collaborative game for arm/hand motor function assessment. The game should entice the patient who wears a HMD, by interacting with the AR environment, to make the movements that are currently used in motion disorder assessment sessions, e.g. pointing and reaching a target, reaching and grasping an object, determining the reachable workspace of the arm (see Figure 1 and Figure 2). Thus, while playing the game, the patient's movements should be recorded and later analysed for an objective evaluation of upper extremity motor dysfunction. The analysis of the recorded data is beyond the scope of this project. Different sensors may be used for tracking (e.g. Kinect for the whole body tracking, Intel RealSense F200 camera or gloves for hand tracking etc.).

Figure 1 Reachable workspace of the arm

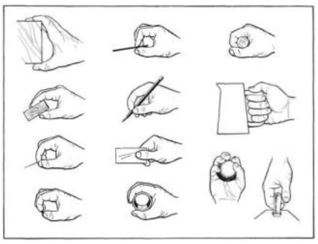

Figure 2 Grasping gestures

The AR framework should enable collaboration between patient and therapist, either local or remote (see Figure 3). This communication functionality is necessary in order for the therapist to adapt dynamically the game to the patient's physical capabilities.

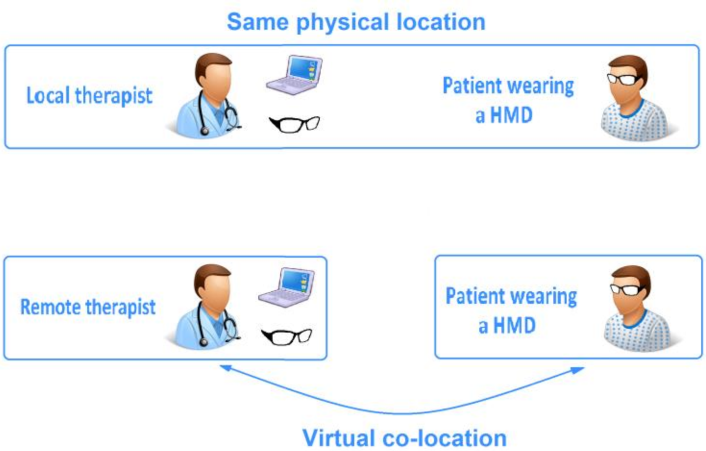

Figure 3 Collaboration between patient and therapist (local or remote)

2. Background information

Different AR systems have already been successfully developed for rehabilitation of the hand and the arm movement in a table-top environment using a projector for augmenting 2D content on the table surface (Hondori et al., 2013) or on the patient's hand (Khademi et al., 2012).

AR not only offers opportunities for patients to conduct exercises, but it also enables the observation and analysis of a patient's motion behaviour. This has been demonstrated in a rehabilitation setting, where Alamri et al. (2010) describe an AR framework for post-stroke rehabilitation that supports the training of daily activities with a cup and shelf exercise. After a training session, the therapist can analyse and adapt the exercises. Luo et al. (2005) describe an AR training environment for post-stroke finger extension rehabilitation, where a therapist can monitor and control the movements of the patients as well as change the environment in real time.

There are many examples of successful AR frameworks that enable collaboration between a local user and a remote one in different (not medical) fields in the recent literature (Adcock et al., 2013; Datcu et al., 2014; Poelman et al. 2012).

The results achieved using AR for rehabilitation, the continuous development of technology for unobtrusive body motion tracking as well as the significant work done in collaborative AR are good premise for the goal of this project.

We recommend the participants to go through the reference list or similar work before the beginning of the eNTERFACE'16 workshop.

3. Detailed technical description

Hardware (as can be provided by us):

- Kinect for full-body 3D motion capture;
- Intel RealSense F200 (RGB and RGB-D) camera for hand tracking;
- Set of gloves from ManusMachina (https://manus-vr.com/);
- Optical See-Through Head Mounted Display (OST-HMD) for stereo visualisation AIRO II from Cinoptics (http://cinoptics.com/product/airo-ii/);
- Meta 1 Developer Kit (https://www.getameta.com/);
- Epson Moverio BT-200;
- Oculus Rift DK1 and Gear VR with Samsung S6;
- Webcams;
- Router for a LAN and Wifi connection;

The participants should have their own laptops running on Windows 8.1 or Window 10.

The **software** in this project will be developed in **Unity3D, using the C# programming language**.
Our intention is not to try to develop new algorithms for hand/body or environment tracking, but to combine and synchronize different Unity3d plugins provided by the manufacturers of the sensors and other open source modules.

For the implementation of the game in AR, the following components might be necessary:

- a marker detection component or a marker-less tracking algorithm of the environment, to provide the link between the real and the virtual worlds (e.g. Vuforia);
- real-time input from the devices that provide coordinates of the joints of the hand and body;
- stereo visualisation of the virtual content in OST–HMD;
- data recordings of all the relevant parameters for motion analysis;
- video streaming to the remote therapist to view the patient while the patient is playing the game;
- a user interface that lets the therapist participate in the game, play and adapt the parameters of the game during playing.

Parts of the system have already been developed and they can be re-used and integrated with the new components. These parts that we already combined are: marker detection from Vuforia; hand tracking from Intel RealSense SDK; stereo visualisation for the OST-HMD AIRO II from Cinoptics; data recordings; network communication with Photon (string messages and Remote Procedure Call (RPC)).

Participants

A team of 5 researchers would be appropriate for the goal of this project in the time allocated. All the participants should have good programming skill in C# and have some experience with Unity3D. Depending on the skills, expertise and preference, each team member will have specific responsibilities in the project.
The optimal participant should have knowledge in:

-game design, interaction design;
-combining and synchronizing APIs from different devices/sensors;
-network communication;
-collaborative technologies and image processing for video streaming.

The critical requirements for candidates in our project are good programming skills in C#, experiences with the Unity3D environment, creativity and possibly some experience in game and interaction design.

Project management

We intend to create 2 sub-teams, one mainly focused on the game design and implementation and the other responsible for enabling collaboration. The works of the 2 sub-teams is expected to be deeply intertwined.

We will be involved in this project, supervising and helping for the implementation in both local and remote ways. In order to ensure that movements made by people while playing the game are relevant for the assessment of upper extremity motor dysfunctions, one of our colleagues (specialist in human movement science) at LUMC will assist us via Skype.

4. Work Plan and Implementation Schedule

The project can make use of earlier results that are already available (Dezentje et al., 2015). Thus, not everything needs to be developed from scratch. In addition, the focus of the project can be adapted to the composition of the project team. However, in order to design and implement a game for motor function assessment, the following major work packages need to be addressed:

WP1. Design of a collaborative AR game that allow for determining reachable workspace

The game should be based on a collaborative gameplay of a patient with one therapist. The gameplay should be engaging for the patient and allow the therapist to challenge the patient to make full use of the reachable workspace. When designing the game, it should be taken into account that the target group of patients is mainly represented by elderly people; a basic list of requirements for the game can be found in (Dezentje et al., 2015).

WP2. Implementation of the game

The game elements for the patient should be displayed in stereo mode using the OST-HMD for 3D visualisation in order to provide an accurate depth perception. The virtual content has to be registered in the real world using open source software packages (e.g. Vuforia, Metaio incorporated in Intel RealSense SDK). The game's implementation should allow interaction through a Natural User Interface and for that purpose different APIs should be integrated and synchronized. For the therapist, different interaction modalities can be considered of which only one needs to be realized. The possible interaction modalities range from a standard 2D user interface via a virtual reality interaction space towards an augmented reality interface when therapist and patient are physically co-located.

WP3. Design and implementation of the AR collaboration support

To enable interaction and collaboration between patient and therapist, we need to design and implement tools that provide:

a. a user interface that allows the therapist to participate in the gameplay (see above for possible interaction modalities). The user interface needs to support dynamic adaptation (control) of the game settings.

b. awareness and presence support for the remote therapist in order to coordinate his/her actions with the patient's actions. This might include video streaming of patient's activities to the remote therapist.

c. the possibility of therapists (both local and remote) to observe and analyse patient's motion behaviour, and to modify the AR exercises to create the optimal situation for the evaluation of a specific patient's motion characteristics.

WP4. Evaluation plan

To evaluate our work in this project, we intend to conduct a short pilot study (with healthy participants) in order to have a feedback on usability and engagement of the game. The goal of this work package is to setup an evaluation plan, incl. the setup of an experiment, the procedures and the necessary material.

	Week 1	Week 2	Week 3	Week 4
WP1				
WP2				
WP3				
WP4				

Deliverables: The software implementation in WP2 and WP3.

5. Benefits of the Research

The novelty of this project is the use of AR technology and serious games to develop a collaborative framework that can be used for objective assessment of the upper extremity motor dysfunction.

The team members will write at least one paper that describes the design and the implementation of the collaborative game developed in this project.

The AR framework will be further used in experiments with patients and therapists from LUMC to explore the capabilities of the hand/body tracking systems to provide accurate data for analysis.

6. Profile of the team

Marina Cidota has a background in Computer Science (focused on Artificial Intelligence) and currently is Postdoc researcher at TU Delft, Faculty of Technology, Policy and Management. Her research focuses on designing for engagement and awareness in a collaborative system, using different interaction techniques and establishing virtual co-location in merging realities. Possible applications can be found in the security domain, in medicine and in certain training contexts. In the current project, Augmented Reality novel technologies, Serious Gaming and marker-less tracking of human body are combined to develop unobtrusive, cost-effective and patient-friendly methods for objective assessment of upper extremity motor dysfunction.

Stephan Lukosch is Associate Professor at TU Delft, Faculty of Technology, Policy and Management. His current research focuses on virtual co-location. Individuals can be virtually at any place in the world and coordinate their activities with others and exchange their experiences. By using augmented reality techniques to merge realities additional information can be provided and visualized, thereby fostering shared understanding. By merging realities complex problems can be solved, complex trainings can be supervised, or complex activities can be guided without all interacting individuals being physically at the same place. In his research, he combines his recent results from intelligent and context-adaptive collaboration support, collaborative storytelling for knowledge elicitation and decision-making, and design patterns for computer-mediated interaction. He is a steering committee member of the special interest group on Computer-Supported Cooperative Work (CSCW) of the German computer science society. He further serves on the editorial board of the Springer Journal of Computer Supported Cooperative Work (CSCW), Journal of Universal Computer Science (J.UCS) and the International Journal of Cooperative Information Systems (IJCIS).

Researchers Needed

Researchers involved in the development of this project should have knowledge in the area of Human Computer Interaction and should have good programming skills in C# for Unity3D game engine. To implement the collaborative component of the AR system, at least one person of the team with additional experience in video streaming is more than welcome.

7. References

1. M. Adcock, S. Anderson, & B. Thomas. "RemoteFusion: real time depth camera fusion for remote collaboration on physical tasks". In Proc. of VRCAI '13, pp. 235-242, 2013.

2. A. Alamri, J. Cha, & A. El-Saddik. AR-REHAB: An Augmented Reality Framework for Poststroke-Patient Rehabilitation. Instrumentation and Measurement, IEEE Transactions on, 59(10), 2554–2563, 2010.

3. D. Datcu, M. Cidota, H. Lukosch, & S. Lukosch. On the Usability of Augmented Reality for Information Exchange in Teams from the Security Domain, Intelligence and Security Informatics Conference (JISIC), 2014 IEEE Joint, pp 160-167, 2014.

4. P. Dezentje, M.A. Cidota, R.M. Clifford, S.G. Lukosch, P.J. Bank, and H.K Lukosc. Designing for Engagement in Augmented Reality Games to Assess Upper Extremity Motor Dysfunctions, IEEE International Symposium on Mixed and Augmented Reality - Media, Art, Social Science, Humanities and Design, 2015, 57-58

5. H.M. Hondori, M. Khademi, L. Dodakian, S.C. Cramer, and C.V. Lopes. A Spatial Augmented Reality Rehab System for Post-Stroke Hand Rehabilitation. In Medicine Meets Virtual Reality ,vol. 184, pp. 279–285, 2013.

6. M. Khademi, H.M Hondori, C.V. Lopes, L. Dodakian, and S.C. Cramer. Haptic Augmented Reality to monitor human arm's stiffness in rehabilitation. In IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES), pp. 892–895, 2012.

7. X. Luo, R.V. Kenyon, T. Kline, H.C. Waldinger, & D.G. Kamper. An augmented reality training environment for post-stroke finger extension rehabilitation. In 9th International Conference on Rehabilitation Robotics ICORR 2005. pp. 329–332, 2005.

8. R. Poelman, O. Akman, S. Lukosch, & P. Jonker. As if Being There: Mediated Reality for Crime Scene Investigation. In CSCW ’12: Proceedings of the 2012 ACM conference on Computer Supported Cooperative Work , pp. 1267–1276, ACM New York, NY, USA, 2012.