MedicalVR: Towards Medical Remote Collaboration Using Virtual Reality

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Abstract
We present a virtual reality framework and assistive tool for design practices for new medical environments, grounded on human visual perception, attention and action. This includes an interactive visualization of shared electronic patient records, previously acquired with a remote tablet device, in a virtual environment incorporating hand tracking, eye tracking and a vision-based peripheral view monitoring. The goal is to influence medical environments' affordances, especially for e-health and m-health applications as well as user experience and design conception for tele-medicine.

Author Keywords
Medical virtual reality; assistive technologies; multi-modal interaction; hand tracking; eye tracking; collaboration

ACM Classification Keywords
H.1.2 [User/Machine Systems]: Human information processing; H.5.2 [User Interfaces]: User-centered design

Introduction
Architects and software architects concerned with designing new medical environments with electronic patient records (EPRs) need to make sure that human-centred design objectives are fulfilled where the environment should meet universal design criteria for both doctors and patients. Since virtual reality (VR) constitutes a highly flexible platform

Figure 1: Our VR setup features an Oculus Rift DK2 HMD with SMI's integrated eye tracking component together with an attached Leap Motion controller for tracking hand movements.

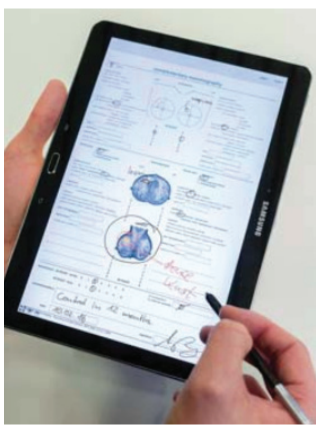

Figure 2: Digital annotation of patient data on a mobile device. Recognized contents are mapped into concepts of medical ontologies in real-time and can be shared with remote collaborators in VR over a network connection.

which allows to create new interactive and fully controllable virtual environments, it has been used in a variety of medical applications like assessment, training, surgery and rehabilitation (see [3] for an overview). In particular, recent advances in head-mounted display (HMD) technology with integrated sensing of human signals like gaze and gesture render VR a promising technology channel for the creation of immersive and personalized collaborative spaces. In fact, gaze-augmented VR can be beneficial in many situations, where spatial configurations have a role to play. For example, deictic referencing by using gaze as a pointing mechanism, or improving situational awareness to enable collaborators to infer each other's intention, based on gaze behavior. Moreover, in the course of the digitization of medical data and related acquisition processes, real-time capable methods for instant knowledge acquisition based on medical ontologies have been presented [5]. These solutions offer great potential for remote consulting of medical experts and collaboration scenarios, which ease time consuming transcription processes and turn-over times of analog paper reports. Our main contribution of this paper is the combination of a mobile instant knowledge acquisition system with an immersive, gaze-augmented VR platform with tracked hand gestures for an interactive 3D visualization and exploration of medical data in order to pave the way for digital, real-time remote collaboration between medical experts. The presented VR demo provides a vision-based spatial perception and cognition simulation environment: with the help of integrated peripheral view analysis, we implement the next generation of design systems for modern medical environments in VR.

Implemented Use Case

Our demo captures a possible collaboration situation in the field of digital breast imaging, in which a radiologist fills and annotates a digital structured report of a patient directly on a mobile device and wants to share this information with a remotely available colleague. For this purpose, the local collaborator sends the recognized and packed data over the network into the VR space of the remote collaborator, where it can be visualized and explored interactively in 3D.

VR Platform

Figure 1 depicts our general VR setup together with an external view of the observed virtual environment. Our configuration consists of an Oculus Rift DK2 HMD equipped with SMI's integrated eye tracking upgrade [4] and a frontally attached Leap Motion controller[1] for tracking hand gestures. Both sensors offer a robust and precise data tracking and are accompanied by dedicated plugins for common game engines with VR support like the Unity game engine[2], which we used for our implementations. The eye tracking plugin offers a built-in easy-to-use and on-the-fly calibration procedure for creating individual user profiles even though the system works uncalibrated for a wide range of users. The hand tracking component comes with a set of predefined VR widgets like buttons, sliders and scrollables which we slightly adapted to our needs allowing for intuitive interactions and an immersive experience. In addition, users can navigate through the virtual scene by means of a simple game controller interface.

Mobile Knowledge Acquisition System

For an instant acquisition of medical data, we use a smartphone implementation and extention [2] of [5] (see Figure 2). The system captures both textual and graphical annotations (free-hand sketches) of a structured mammography report while providing real-time feedback and allows for practical on-the-fly corrections. On demand, a filled report

[1] https://www.leapmotion.com
[2] https://unity3d.com

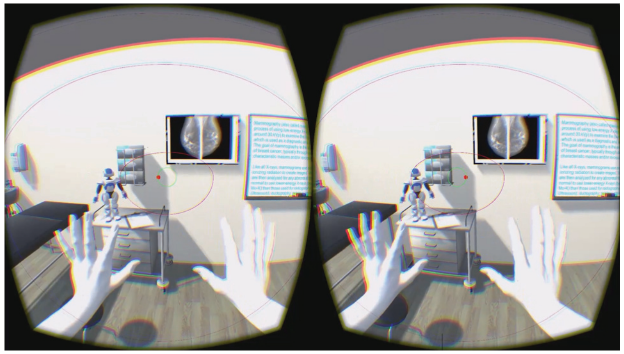

Figure 3: Interactive doctor's office in VR with different input modalities. Visualizations include the position of gaze (red dot), peripheral regions of the human visual field (colored elliptic shapes) and a virtual 3D representation of the user's hands.

can be sent to a specified network address of a Unity server where it can be visualized and discussed in VR.

Peripheral View Analysis
Accounting for situational awareness and an extended evaluation of human spatial perception in a specific context, we complemented our gaze-based user interface by a general 3D peripheral view calculation model for eye tracking applications based on characteristics of the human visual field [1]. The model maps context-related objects of interest to different regions of the visual field around the center of gaze (see Figure 3) and determines the corresponding visibility to the observer based on characteristics of these regions and the observed size of the object. This enables our system to compensate weaknesses of human peripheral vision by providing proactive and assistive behavior in terms of adapted object augmentations and attentional shifts.

Demo
The concept of our demo looks as follows. First, a local expert fills a structured report directly on a tablet device using textual annotations and free-hand sketches with a pen and sends the captured patient data via a network connection to the VR space of an available remote collaborator who the local expert wants to consult instantly for a discussion of medical findings. Hence, for the remote collaborator, the incoming information constitutes a contextual object of interest and is analyzed with respect to its perceptual status for the observer as can be seen in the left picture of Figure 4. In case, the information is located in peripheral regions of the observer's visual field, where visual acuity falls off rapidly with increasing distance from the center of gaze, or at large distance to the observer, the system aims at triggering a shift of attention by showing a blinking, colored augmentation for the object of interest. As remote collaborators reduce their distance to the shared EPR by manual navigation through the virtual environment and focus their attention on the data, visual overlays turn to a more detailed description (see middle picture of Figure 4). In this context, the integrated peripheral view monitoring component offers a management of several augmentation layers with varying level of detail depending on the determined visibility. Finally, the annotated report is transferred to a set of virtual widgets (e.g. scrollables) that respond to tracked hand movements of the remote expert. In this respect, the patient data can be visualized and explored interactively at virtual clip- or whiteboards as shown by the last image of Figure 4.

Conclusion and Future Work
We presented an immersive, perception-based VR framework, which accounts for the sensing and interpretation of multiple human signals. In combination with a mobile digital reporting system, our framework outlines new ways of real-time collaboration and human-centered design aspects

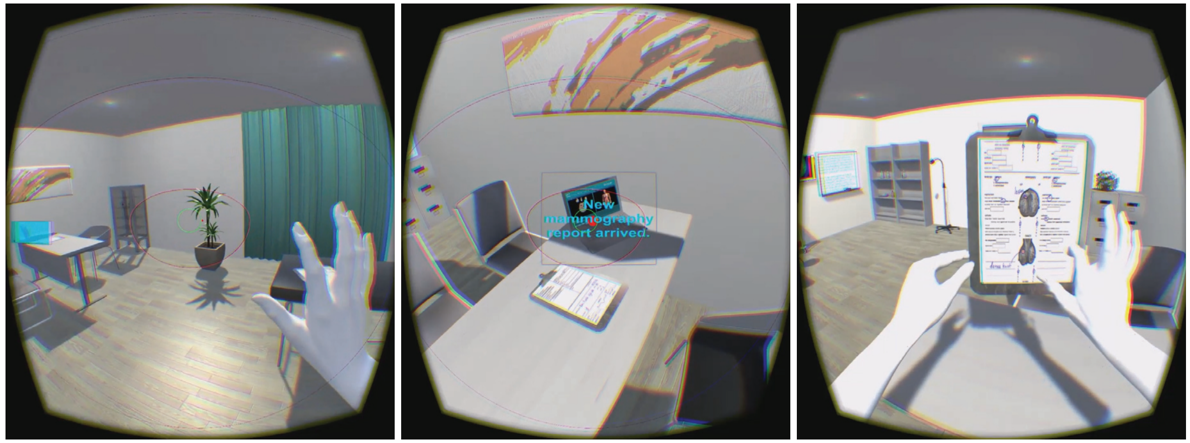

Figure 4: Our implemented medical use case. *Left:* In case a remote collaborator would like to share an EPR, the context-aware peripheral analysis component of our system informs the user by visual augmentations (blue highlighting). *Middle:* Based on the visibility of the object of interest to the user, more detailed information overlays are presented. *Right:* Interactive visualisation/exploration of annotated patient data. See demo video at https://www.dropbox.com/s/2bkmn8vzmtmrvl2/file167-1.mp4.

in modern tele-medicine. Our future research will focus on the evaluation and implementation of more complex interaction and visualization techniques allowing for an even better user experience.

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