BewARe - Sensor-based Augmented Reality system for individualized endurance training for elderly people

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ABSTRACT

We present a novel interdisciplinary project to develop a sensor-based Augment Reality (AR) system for individualized endurance training for elderly people. This distributed system supports interaction for users of old age and suggests individualised exercises by a therapist avatar. Based on sensor data acquired from the patients during training sessions the system adapts to patients individual training needs and thereby serves as a non-drug therapy for people with hypertension.

1 INTRODUCTION

Regular physical activity has the biggest impact on health and well-being besides healthy nutrition. In addition to the preventive effect of physical activity, almost all chronic diseases (e.g., asthma, osteoporosis, diabetes) are positively affected by physical activity. In particular, in the chronic illness with the highest prevalence in Germany - hypertension - which affects 85% of people over 70 year of age, physical activity plays a major role as a non-drug treatment [15]. Particularly recommended is endurance training for patients with essential hypertension (systolic < 160 mmHg, diastolic < 100 mmHg) [8]. Through individual endurance training cardiac resilience and performance reserves can be increased, a reduction in coronary risk factors and an improvement in anaerobic metabolism can be achieved.

Increasing integration of digital technologies in healthcare, rising spending, focusing on providing efficient healthcare services, and educating professionals are some of the key factors driving the increasing adoption of AR and VR technologies in healthcare [23, 11, 21]. Those technologies are successfully used, including: 3D surgery simulations, pain therapy, EMDR therapy, depression and cancer therapy, assisted living. The multitude of new technologies in the field of AR and wearables offer the opportunity to support people of old age.

In this interdisciplinary project of computer scientists, engineers and physiotherapists we envision and develop an intelligent and interactive multi-user AR system that can be used to create a location- and time-independent individual training. This training enable older people to exercise under controlled conditions. Figure 1 shows the overall concept of such a system and its components starting an expert designed catalog of exercises. During training sessions sensor data is monitored and evaluated. The system suggests improvements to the patients based on the evaluated data in the training. Improvements and personal data are displayed in AR with a user experience specifically designed for the needs of older people. Over time, a personalized model of each patient is build to further individualize the training program. Decisive to the success of such a system is how intuitively the user can interact with the system and furthermore what hints, suggestions or improvements the system can make to the patient.

An additional aspect to increase the user's motivation is *gamification*, which can lead to positive behavioral changes that strengthen long-term motivation. Similar to games, systems with gamification elements can also intrinsically motivate the initiation and continuation of healthy behaviors [7, 25, 26]. Current examples of the use of gamification in healthcare cover all important health risks, including physical activity, rehabilitation, patient activation in chronic diseases such as diabetes, cancer or asthma, diet and weight management, drug compliance, and mental well-being [10, 26].

An intelligent system, that is based on the user data, enables the creation of a model, which can be presented to the attending physician or therapist on the AR, allowing him to experience programs in his real environment from the perspective of the patient. The project of our sensor-based AR system focuses on two key aspects:

1. Augmented reality and sensor technology in movement, coordination and reaction training for geriatric medicine. This includes gamification approaches to increase motivation, change behavior, and strengthen resilience and persistence.

2. AR and sensors as an interface for an intelligent system to support seniors' health issues. The use of the AR glasses offers the possibility to capture the environment, what is seen or heard, to derive information from it and to give it back to the user through the use of an intelligent system in the background. For additional insights we employ an eye-tracker with the AR glasses.

Contributions. We propose an AR system which encourages elderly people to participate in exercises and therefore improve their health. Our system leverages a combination of different sensor inputs like rgb- and depth-cameras, acceleration sensors, eye tracking devices and wristbands to measures blood pressure and heart frequency. An early prototype, realized with a Microsoft HoloLens, allowed us to give older people an idea about new concepts of individual training (Figure 1). The acceptance of patients for such a system was high. In addition, valuable information such as requests for training scenarios, visualization displays and other hardware-specific requirements for the system were determined. We're actively developing further concepts to suit the needs of individual endurance training in order to improve healt of elderly people.

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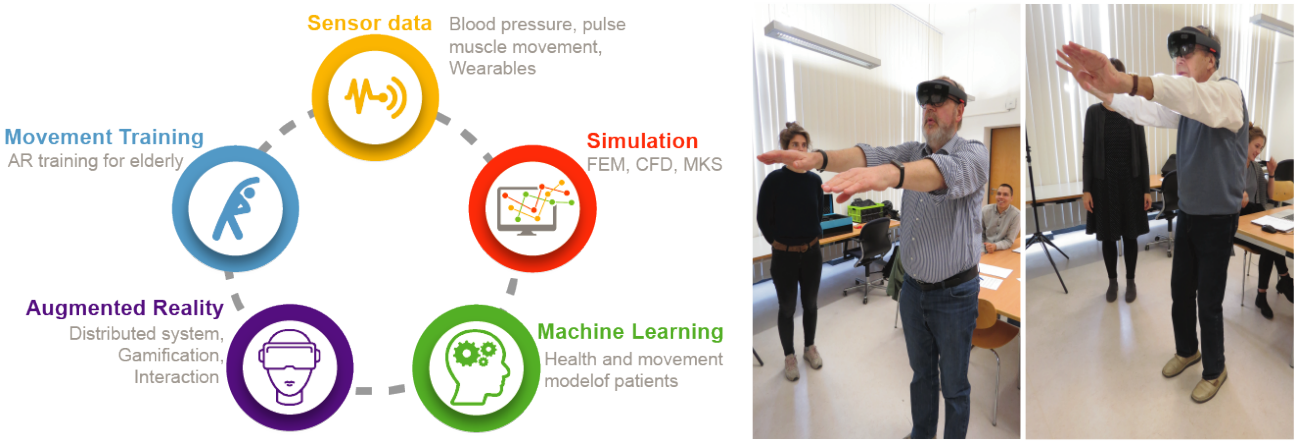

Figure 1: (Left) Illustrates the general closed concept of the proposed movement training. The AR system supports comprehensive interaction for elderly users and suggests individualised exercises by a trainer avatar. Based on sensor data acquired from the patients during training sessions we drive a simulation model that in combination with machine learning models adapt the exercises. (Right) Shows first tests in a controlled testing environment.

2 Related Work

Exercise training has been used as an effective tool in the treatment of hypertension for over 20 years [1]. In the area of non-pharmacological measures, endurance-oriented physical and physical activities have become established [21]. Studies show that adequate training lowers blood pressure and prevents other resulting diseases [5, 16]. However, a diagnostic examination as well as an adequate selection, dosage and intensity of the initiated movement therapy are required [21]. Studies show that regular exercise can prevent or counter prevent non-communicable diseases. Technical support systems, such as smartphone applications, can increase physical activity and can positively influence the patient's relationship to active movement. Like a cascade, this positive effect can positively influence family and individual social contacts [3]. In Germany, the number of health applications used, such as fitness bracelets, smartwatches and smartphones, is continually increasing. A representative survey by Bitkom Research found that 31% of Germans collect their health data with fitness trackers [17]. Many patients believe (65%) that using wearable technologies can increase general health by tracking vital signs. There is therefore great potential in the use of portable sensors in the prevention of diseases and the medical care of patients. However, in addition, the execution of the therapeutic movements is crucial to the success of the treatment. In this regard, studies have been conducted examining smartphone applications that examine in real time the movement of patients and possibly correct during training. The goal is to achieve fewer errors in the exercises and to determine an individual learning process. In the study by Rospo et al. [24] the subjects are guided through an app to perform exercises, which had the same effect as a guide in a gym.

2.1 Interaction design for seniors

The use and acceptance of AR glasses by seniors has been little researched so far. However, different studies [18, 19] have shown that seniors consider VR and AR applications to be useful. It is also reported to have operational issues due to low usability and lack of experience with older users. The aim of the project is a consistent user involvement and the creation of a user-friendly interface and an intuitive interaction design. Furthermore, the balance changes and the potential risk of falling must be taken into account. Interaction design for older people not only has to consider the discrepancy in mental models [12, 14], but also to use the motivation for seniors for new technologies. For this purpose, gamification approaches are developed in a user-oriented manner and tested in iterative design in order to identify the best possible solutions for increasing motivation, strengthening resilience and ensuring persistence.

2.2 Augmented Reality and Machine Learning

To improve immersion and support users by combining the AR system with sensors and interaction we employ recent machine learning approaches. There are a number of important points of contact for this project. One example is the recognition and localization of objects in real scenes in combination with tactile feedback, for example to guide users with impaired vision [13, 6]. Other approaches involve the 3D reconstruction of interiors [4], eye examination tracker [20] and and the ability to visually enhance image content [9].

Especially with regard to the therapy and diagnostic context of geriatric medicine, those approaches should enhance the outcome of the system. Therefore, in the project, research findings of the above-mentioned aspects are linked with the AR system.

2.3 Wearables and Simulation

Wearables today are on the one hand miniaturized computers and on the other hand sensors that record data. By interconnecting the wearables with each other, it is possible for the user to "scrutinize" his body (Quantified Self). Accordingly, Quantified Self groups serve to connect users, developers and providers of digital sports and health products. Quantified Self methods use not only purely biological information but also psychological tests, medical self-diagnosis services and much more. With the help of the recorded data, the user has a decision support that allows him to make informed decisions based on his data [2, 22]. Thereby, the user has the control over which health data he wants to share exactly with whom and when. The aim of the BewARe project is to create a model of one's own state of health adapted to the respective user, based of the sensor data, that makes it possible to make predictions based on the evaluation of parametric simulations, in addition to the usual pure data. These "metadata" can then be evaluated by both the patient and the therapist. Here, in a first step, the modeling of the mechanical body by means of multi-body models is to be limited in particular, since it has great significance in the creation of movement programs. Special attention should be paid to smart textiles, i.e. electronic technologies and computers, which are incorporated into garments or accessories and can be worn on the body [27].

3 General Approach

The aim of the project BewARe is the development of technically supported exercises and agility training for seniors with hypertension based on an intelligent AR system. Different exercises from the training components endurance, strength, flexibility and coordination are provided and individual stress norms are considered.

We implement a training concept for patients with hypertension as a distributed multi-user AR system in which a mobility training supervised by therapists is carried out. The training contents are presented to the user via AR glasses. With the glasses it is possible for the patient to train independent of time and place. The technically assisted exercise training can also be offered within the physiotherapy and in group sessions in the clinic / rehabilitation facilities or nursing homes (see Figure 1).

The AR goggles are at the heart of the system as an intelligent recording and output device and are used in three ways that rely on machine intelligence:

1. With the device serving as an environmental sensor an evaluation of the user environment is employed.

2. With the integration of sensors, wearables and an eye tracker an evaluation of the patient himself is possible.

3. Recorded data is stored in an administrative, web-based database system allowing therapists and patients to access exercise and health plans. An interaction concept and design especially adapted to the elderly allows intuitive access to the system by carrying out a series of coordinated exercise units with gamification elements.

In order to increase the compliance of patients to the training, various motivational components such as auditory, visual, and tactile feedback, as well as gamification elements are integrated. The integration of gamification elements will play an important role in shaping user experience, motivation for regular use and long-term impact. In addition to the patient, the therapist also has the opportunity to view and supervise the progress of the training. He receives additional information through close-to-body and ambience sensors, which record different vital signs relevant to exercise (eg. heart rate, oxygen saturation, stress level) as well as individual parameters such as gait patterns, etc. These can be worn as wearables or textiles or integrated in exercise equipment (dumbbells, exercise balls). The use of wearables is extended to build individual simulation models (e.g. multi-body models) based on the data. The system allows the treating therapist to play through a motion program and adapt it to the patient's real environment.

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