A Prototype of Virtual Reality Based System for Investigation of Peripheral Vestibular Disorders

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Introduction. The spatial orientation in relation to the Earth's gravitational axis is important for the maintenance of the posture, gait and other human motor activities [1]. In order to increase accuracy and precision, data fusion from four different sensory systems takes place in human body: the interoceptive, visual, somatosensory and vestibular. Different tests are proposed to evaluate vestibular system [1, 2]. One of the tests investigates the role of visual and vestibular information in verticality perception and is named subjective visual vertical (SVV) assessment. SVV tests integrity of visual and vestibular otolithic information and is usually performed by the usage of simple devices like rotating bars or more complex computer based systems [2]. PC based system makes use of computer monitor and dedicated software for presentation to the patient of special visual stimulus.

Recently virtual reality (VR) systems of acceptable quality became affordable with the appearance of Oculus Rift [3] and Samsung Gear VR [4]. The later even does not need wires and PC. These systems allow formation of wide field view 3 D static and moving images and in addition are able to track subject's head orientation in 3 D space with high speed inertial measurement unit sensor. It is thought that new VR systems will change the gaming and entertainment worlds. However, professional applications of VR systems will grow as well in: architecture/urban planning, scientific visualisation, professional training. Here we present our first attempt to apply VR system as a medical measurement instrument for evaluation of peripheral vestibular system with SVV test.

Materials and methods. The proposed system consists of two main parts: Oculus Rift 1 VR system and computer with dedicated software (Fig. 1.). VR system Oculus Rift 1 has the following specifications: display resolution 1280×800 (640×800 per eye), field of vision 110°, 3 degrees of freedom rotational tracking sensor with 1000 Hz sampling rate. These specifications allow building simple and complex visual stimulus for our application.

The SVV test software is built using Unity (computer game building software) in C# programing language. This software renders the target object in

Oculus Rift display and patient is asked to roll his head until he feels that object shown in the display is vertical. The orientation of the Oculus Rift headset (and patient head) is sent to the control box and then to the computer of health professional.

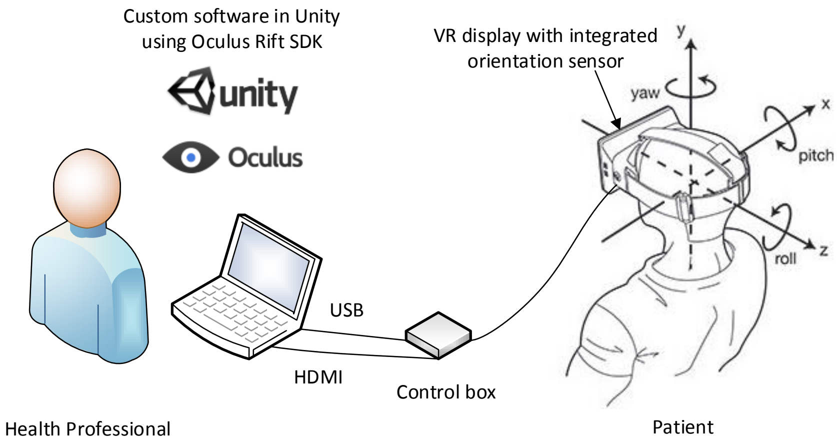

Fig. 1. Hardware and software components of the system

The test may be performed with different target objects (Fig. 2.).Fig. 3. shows use case diagram of the proposed system. The Health Professional is able to select a target image and a test type. Test type decides the type of moving distraction presented to the patient together with the target image. The distraction objects can move clockwise or counterclockwise. If the health professional starts the test, the application starts automatically. The "rift" application presents the visual stimulus in the Oculus Rift display and sends orientation data back to PC. The "doc" application receives data in the same moment. The communication between the applications is asynchronous. The patient controls the "rift" application by moving his head and keyboard: by pressing spacebar key he finishes the test.

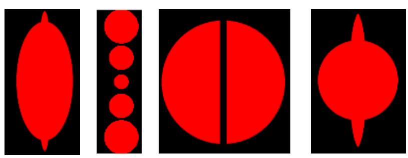

Fig. 2. Possible target object images

In addition to SVV test, there was implemented possibility to track orientation trajectory of the patient's head in 2 D. This feature allows recording dynamic changes of the patient's head orientation while standing still (posturography) with changing visual stimulus in VR display. Analysis of recorded patterns of 2 D trajectory could potentially provide diagnostic value.

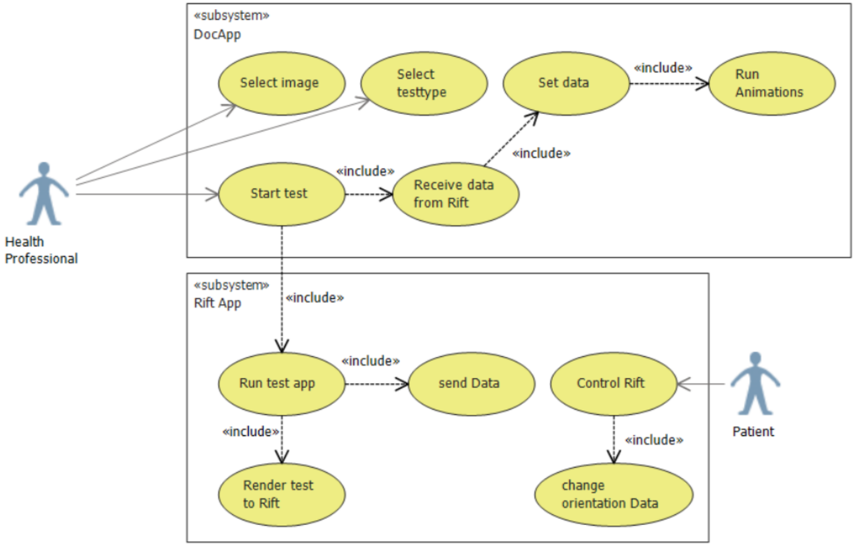

Fig. 3. Use case diagram of the proposed system

Results. General view of the proposed system is seen in the Fig. 4. (left). The patient can be sitting or standing during the SVV test. All 3 orientation angles are registered after test finishes with the press of the spacebar in the keyboard.

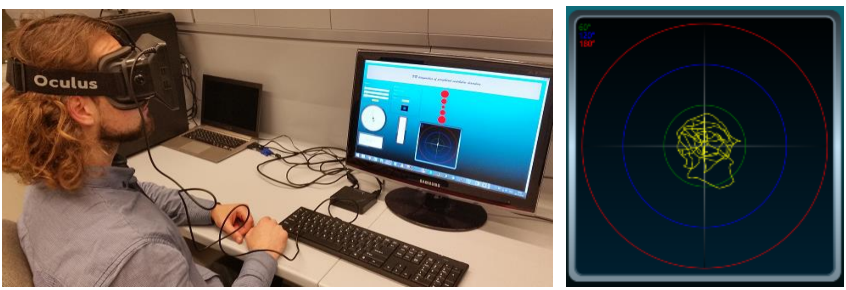

Fig. 4. View of the proposed system (left), orientation trajectory of the patient's head in 2 D (right)

There was registered one 2 D orientation tracking example (Fig. 4, right). It shows random distribution of head's orientation in space during standing still on two feet. We could expect the different patterns during presentation of visual stimulus and in pathology of vestibular system.

Discussion. There a first prototype of the Oculus Rift VR based system for investigation of peripheral vestibular disorders is proposed in this work.

Preliminary tests show that stimulus images presented to the patient are of adequate quality during relatively slow head orientation changes. High end computing power would be needed in order to mitigate latency in dynamic visual stimulus presentation during fast orientation changes of the head. Preliminary tests show that head orientation tracker has low latency and adequate accuracy. These findings indicate that Oculus Rift VR has potential in building innovative diagnostic tests for investigation of vestibular disorders.

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A prototype of virtual reality based system for investigation of peripheral vestibular disorders was presented. The prototype system uses low cost virtual reality headset Oculus Rift 1 with built in head orientation tracker and custom developed software for Unity game engine. There were two tests implemented for investigation of peripheral vestibular disorders: subjective vertical and posturography. Good quality and low price, high accuracy and low latency of the system allows building potentially new diagnostic tests for investigation of vestibular disorders.