Testing Oculus Rift Virtual Reality Headset Applicability to Medical Assistive Systems

Ivo R. Draganov[1], Nikolay N. Neshov [2], Darko Brodic[3]

***Abstract* – In this paper are shown results from initial testing of the Oculus Rift virtual reality headset in relation to basic movements of the human head. Number of subjects were given series of instructions through the virtual environment with a moving cursor to follow from left-to-right, top-to-bottom and from horizontal-to-vertical-to-horizontal position of their heads. Mean and deviation values are obtained for rotation angles in space by the embedded sensors which show the possibilities of using the headset in some medical assistive systems.**

***Keywords* – Oculus Rift, Virtual Reality, Medical Assistive Systems**

I. INTRODUCTION

Virtual reality opens up a full new frontier in assisting motor disabled patients during both their rehabilitation and implementing ordinary duties. Although not intended for professional purposes a number of companies, such as Canon, Sony, Motorola, Philips, Olympus, Epson and others, presented to the market low priced head mounted displays for virtual reality at relatively low price. In this study one of the most popular such headsets is used for probing its applicability in applications for medical assistive systesms.

In [1] Reinke et al. describe a newly developed prototype of virtually reality based system for investigation of peripheral vestibular disorders. Considering mainly the spatial orientation of the human head to the gravitational axis of the Earth which is crucial for proper human posture, gait and large amount of motor activities they combine the visual and vestibular information in perception along the vertical to estimate the type and degree of a vestibular disorder. The proposed system consists of Oculus Rift display and dedicated software where a certain object is presented to the patient and then he/she is asked to move his/her head to a position where the object appears vertical. Medical personnel can select the type of target object from a database and gets as a feedback the relative position of the head at end point creating a record in another database for further examination and possibly comparison over a long period of time with results from previous tests. The authors consider all target objects to retain tolerably good quality along all tests with the different movements of the head and the latency of the sensor to be adequately low preserving the desired accuracy.

Wood [2] proposed a model for more advanced system incorporating virtual reality in the form of gaming chair. His goal was to achieve motion based on events from control software and user input along 3 axis of movement. There is a resemblance with flight simulators in functionality about this system but at much more lower cost. A syntactic feedback was provided to the user by Oculus Rift as additional feature in comparison to already developed such systems while preserving safety at first place and assuring precision, longevity, usability, and compactness.

Another practical solution in a simpler form for distance control was developed by Burström et al. [3] called Desktopulus. It is a system putting together the Oculus Rift and Leap Motion with software tools for building up a virtual workspace for office needs. Embedding natural gestures by the user another degree of freedom was added to the user. On a virtual desktop environment are placed a set of different tools as in traditional desktops which can be manipulated by grab, move and circle movements. High CPU power consumption was reported for smooth operation of the system. Hence some optimization procedures need to be further applied in order to make the system affordable to the mass user with lower hardware requirements.

Another application of the Oculus Rift was presented by Paolantonio et al. in [4]. It is a 3D virtual representation of drones' flights in web browsers using globes visualization technology Cesium.js. Processing telemetry data, digital elevation models, georeferenced images and mosaics by the GDAL software and OGC web services (WMS, WFS). The user can virtually feel the flight. The proposed system use two types of data storage – a raster and a vector one, first of which located directly over a file system and the second over a PostGIS. The web map service exploits mosaic and pyramid representations. The first one takes a set of georeferenced images focusing on an area of interest forming a new continuous scene. The second one is based on collection of multiple mosaics each one of which is connected to different zoom level. The input telemetry data is processed in three steps: shapefile creation leading to a layer of points, database upload as a table to vector data storage, and finally exposing the database to the server. The creation of 3D globes and 2D maps in the web browser is done by the JavaScript library Cesium.js. It uses WebGL with hardware-accelerated graphics and is efficient for dynamic-data visualization. When presenting the scene to the user it's taking the advantage of the Cesium Sensor plugin. A pyramidal cone is generated pointing to the current telemetry point in time where the projection angles are of 50° horizontally and 70° vertically. They are selected equal to the design parameters of the Canon PowerShot S110 camera most frequently used in these applications. Viewing the scenes by the Oculus Rift it was possible to move by user selection up/down, forward/backward, right/left and also to duplicate movement's

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velocity while looking straight to the horizon or to overlook the surface from above.

Some other problems often met with the head mounted displays are the focus cues, accommodation and retinal-image blur which were addressed by Konrad in his study in [5]. Both the object space methods where the depth of field effects are made straight into the rendering pipeline and the image space methods where all images are rendered at focus and then by a depth map undergo partial blur are considered by the study. Since the latency is the most important factor in these systems image space methods being more time efficient at the loss of some accuracy have higher priority for improvement. Konrad propose the linear filtering by Gaussian function for adding depth of field. The filter is spatially variant with depth-dependent point spread function and filtering time is proportional to the size of it. Separability of the Gaussian filter is considered as a way of lowering execution time. Another solution suggested by Konrad is the use of adaptive bilateral filter with weights proportional to depth values for the neighboring pixels. When a foreground is being captured in focus the blurred background will not occlude a portion of it blurring it as well. Since the bilateral filter preserves edges intensity leakage is reduced and results are better than the Gaussian filter. Execution time in this case is higher. The last approach proposed by Konrad is based on natural heat diffusion. As the time passes by uneven heat distribution over a conductive object tends to diffuse to more even one which has a similarity with image blur. Using the already developed mathematical apparatus consisting of differential equations for the heat diffusion it is possible to easily model the blur process. Computational time is highest for this approach but results are most promising.

In [6] it is given an extensive comparison about the capabilities between the Oculus Rift DK2 and Project Morpheus (PM) head mounted sets by Goradia et al. While the Oculus Rift is supported by PCs and mobile devices the PM is intended to work with PlayStation console only. The first set has 7” panel size against the 5” of the latter. Both sets have native resolution of 1920pixels along the horizontal and 1080 pixels along the vertical which gives resolution per eye of about 960x1080 pixels. The Oculus Rift DK2 is made by using OLED technology while the PM uses LCD. The maximum refresh rate of the PM is less than 2 ms typical for the Oculus Rift. Apart from the gyroscope and accelerometer the Oculus Rift possesses also a magnetometer. The inertial update rate for both units is 1000 Hz and the field of view of the PM is 90° using also the PlayStation camera - with 10° less than the Oculus Rift’s equipped with a near infrared CMOS camera. The outputs are 1USB 2.0 and 1 HDMI where only the PM has 1 headphone output intended for 3D audio. Both sets are ready to be used in industrial type applications with the appropriate software as the one described in [7].

In the following Section II a prototype of a new medical assistive system for motor disabled patients is proposed with a protocol for testing the Oculus Rift inside it. Then in Section III some experimental results are presented from this testing followed by a conclusion in Section IV.

II. MEDICAL ASSISTIVE SYSTEM FOR MOTOR DISABLED PATIENTS AND EXPERIMENTAL SETUP

The medical system proposed in this paper is intended for assistance of patients with fully immobilized lower limbs and partly lively upper limbs. The main purpose of the system is to help the motor disabled patient with rehabilitation procedures where a series of training tasks should be accomplished by both hands. Each hand must be equipped with a sensor glove and the subject must wear the Oculus Rift. The exercises that need to be performed are stored in an indexed form in a database. Using a scene composition software module ghostly images of the hands of the patient are virtually generated inside a full training scene and then passed along to the virtual reality render for viewing through the Oculus Rift. Trying to repeat each movement of the “target hands” with his/her own the disabled person produces head’s and hands’ motions detected by the sensor gloves (using sensor gloves controller) and the Oculus Rift (through the accelerometer, gyroscope, and magnetometer) which are analyzed through another software module called movement analysis. Either at the same place or from a distance by remote connection a specialist on rehabilitation can get in real time or off-line the results of the exercise program. They are presented in the form of spatial differences by position at given time markers for both hands separately considering their volumetric properties.

The experimental setup includes a healthy individual (subject) that was presented a test pattern (marker) corresponding to the higher human eye resolution both horizontally and vertically rather than diagonally. He needed to track its movement first from Upper-Left to Down-Right position and then from Upper-Right to Down-Left position for a period of 11 sec. For each experiment the rotation angles (Fig. 1) around the three coordinate axes were measured for 10 repetitions in total.

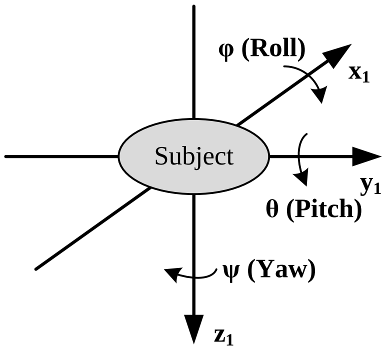

Fig. 1. Reference coordinate system for the subject

The resulting position and orientation from each movement of the head could be represented by a series of vectors with the following structure – $\{[t_0, x_0, y_0, z_0], [t_1, x_1, y_1, z_1], \ldots, [t_k, x_k, y_k, z_k], \ldots, [t_N, x_N, y_N, z_N]\}$ where t_k is the current moment of time for estimating the position and $\Delta t = t_k - t_{k-1} = 1$ sec for $N = 11$ sec in this case for the position. The orientation is given by $\{[t_0, q_{00}, q_{10}, q_{20}, q_{30}], [t_1, q_{01}, q_{11}, q_{21}, q_{31}], \ldots, [t_k, q_{0k}, q_{1k}, q_{2k}, q_{3k}], \ldots, [t_N, q_{0N}, q_{1N}, q_{2N}, q_{3N}]\}$ where $q_{0k}, q_{1k}, q_{2k}, q_{3k}$ are the components of the quaternion Q found from the roll (θ), pitch (φ), and yaw (ψ) as suggested in

[6]. It could be found in general form for arbitrary spatial rotation by considering at first the yaw rotation (Fig. 2) according to (1):

$$R_1^{s1} = \begin{bmatrix} \cos\psi & \sin\psi & 0 \\ -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix}. \qquad (1)$$

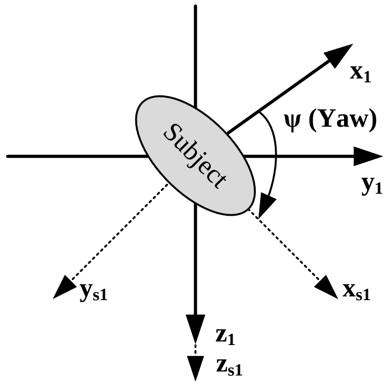

Fig. 2. Yaw rotation component of the subject

Taking both yaw and pitch rotation together (Fig. 3) a more detailed transform is obtained using (2):

$$R_{s1}^{s2}(\theta) = \begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix}, \qquad (2)$$

to the form of:

$$R_1^{s2}(\theta,\psi) = R_{s1}^{s2}(\theta) R_1^{s1}(\psi). \qquad (3)$$

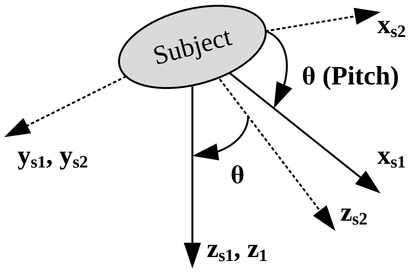

Fig. 3. Simultaneous yaw and pitch rotation of the subject

Finally combining the roll rotation based on (4) transformation matrix:

$$R_{s2}^{2}(\varphi) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\varphi & \sin\varphi \\ 0 & -\sin\varphi & \cos\varphi \end{bmatrix}, \qquad (4)$$

a full description of the whole rotation (Fig. 4) could be written in general form according to:

$$R_1^{2}(\varphi,\theta,\psi) = R_{s2}^{2}(\varphi) R_{s1}^{s2}(\theta) R_1^{s1}(\psi). \qquad (5)$$

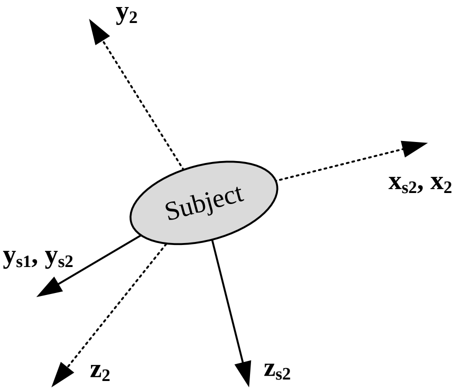

Fig. 4. Yaw, pitch and roll rotations combined

III. EXPERIMENTAL RESULTS

The average values of the pitch, yaw and roll for moving from Upper-Left to Down-Right position of the head are given in Fig. 5.

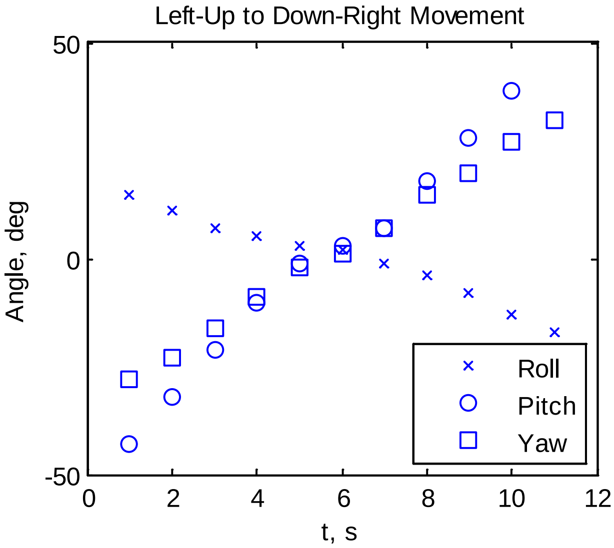

Fig. 5. Pitch, yaw and roll change when performing Upper-Left to Down-Right motion

The analysis of the angles change when performing the Upper-Left to Down-Right movement about their average magnitudes reveal most increase for the pitch (Fig. 5). It starts from -43° and ends up at 50° changing relatively smoothly. It is followed by yaw change from -28° up to 32° and with least decrease is the roll – from 15° down to -17°. During the medium time intervals the diversion from linearly changing values was around 2-3° at most cases.

Somewhat the opposite is the situation with all three angles when performing Upper-Left to Down-Right movement. Here the changes are also relatively smooth with pitch increasing from -47° to 52°, followed by decreasing of yaw from 27° to -33 and with smallest deviation is the roll – from -16° to 14°.

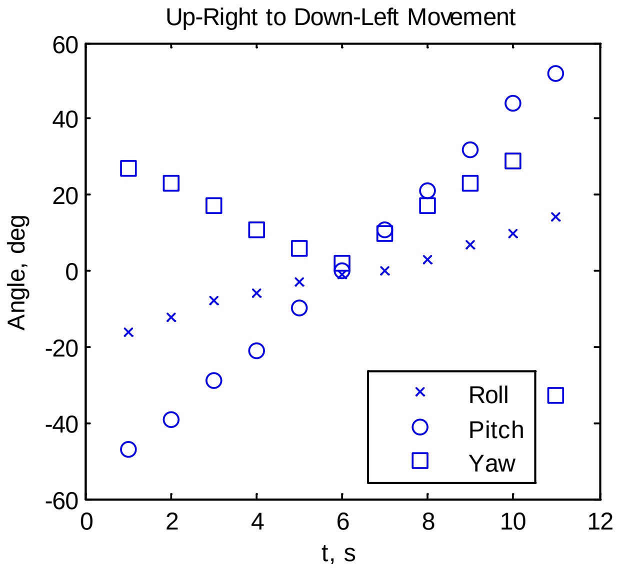

Fig. 6. Pitch, yaw and roll change when performing Upper-Right to Down-Left motion

All these results reveal that the movement analysis module should not be implemented in a straight-forward manner. All deviations for each angle should be carefully estimated for every patient at the time of initial calibration of the system. In order to have objective assessment of the results from therapy from the medical personnel all future deviations should be compared to initial ones and proper conclusions made on that basis.

IV. CONCLUSION

In this paper a testing of the Oculus Rift virtual reality headset was presented based on analysis of the Upper-Left to Down-Right and Upper-Right to Down-Left motion of a human head to evaluate the precision and time efficiency in relation to its applicability to a newly proposed medical assistive systems. The results are promising which provides a reliable displaying mean at low cost for virtual involvement of patients during their rehabilitation.

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