CONTROL AND SCENES DESIGN FOR AFFECTING HUMAN POSTURE BY VISUAL STIMULUS

T. Lukáč, J. Púčik, O. Ondráček

Institute of Electronics and Photonics, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology

Abstract

In this paper we describe a development of the system for controlling a visual stimulus in posturography. We developed system controlled by Matlab that measure, acquire, and analyze posturographic parameters. It also starts and stops visual scenes in a media player. The scenes are made for the visual stimulus that has to destabilize a human posture in the predicted way – medio-lateral or anterior-posterior direction. The human posture is measured with so called force plate that senses vertical projection of a human center of mass on the plate in a form of ground reaction forces. A stimulus causes a larger sway of the center of mass. The visual stimulus is delivered with a head mounted display device – Oculus Rift – a new emerging trend in the gaming devices. The visual stimuli for this technology are developed differently from a conventional way of delivering the visual stimuli with a projector and a projection screen. Video frame consists of different picture for each eye and so the pictures need to be transformed accordingly. This is due to the fact that display is close to the eyes of a patient. A technique for a stimulus video preparation is described.

1 Visual stimulus in posturography

Controlling a posture is a complicated process. In engineering terms, it involves actuators (musculoskeletal systems), controller (central nervous system), and sensors (visual, vestibular, somatosensory systems). These systems works together resulting in a never-ending sway of human body. Worsening any of these systems can lead to malfunction or even a failure that can end in a person`s fall. [1] Investigating posture consists of an examination in a quiet standing – static posturography, or a movement of the standing base – dynamic posturography. Other ways involves stimulation of the sensory systems. These stimulation causes body to sway in the direction of the stimulation. Vestibular system is stimulated with galvanic stimulation. Somatosensory system is usually stimulated with a motor with eccentric weights placed on the legs. Visual stimulation is delivered by various means. These includes means from simple but effective devices like rotation disc [2] to the most complicated and expensive systems known as CAVE [3], NAVE [4], BNAVE [5]. Alternative ways are provided with video scenes displayed on the screen with projector [6] or displayed with head mounted display (HMD) devices [7] like the recent product made for gaming – Oculus Rift. HMD devices have a few problems, such as reduced field of view and require additional image preparation and adjustment for stereovision. It was shown in [8] that reduced field of view has effect on body sway.

2 Measuring and acquiring posturographic data

Posturographics measurements aim for depicting the movement of the body center of mass (COM) in time. COM is said to be a controlling variable as it has to stay within the base of support that is defined with the position of legs on the ground or as in posturographic measurements with the position of the feet (heel together toes apart with 30° angle – like the letter "V") [9]. Measuring the COM movements is not an easy task as its position in the body is not constant over time. Methods developed for tracking COM movements consists of systems like OPTOTRAK [10] or Zebris. These track the markers placed on the body segments. From markers movements a movement of the COM can be calculated. Another commonly used method is measuring projection of the COM onto the ground with so called force plate [2, 6]. Force plate usually consists of three sensor like tensometers or piezoelectric transducers. Ground reaction forces (GRF) are measured and, consequently, center of pressure is calculated.

The program is developed in Matlab environment that communicates with National Instruments data-acquisition system NI USB 6008 through calling external functions (*dll libraries - callib*). NI USB 6008 measures GRF with sampling frequency of 100 Hz, Matlab program acquires data, calculates center of pressure, and displays it in real-time. A complex set of measurement is in disposition – from quiet standing to multiple stimulation measurement. Our Matlab program is capable of controlling galvanic vestibular and somatosensory (dc motor) stimulation that are started in the concrete time through NI USB 6008 analog output. Visual stimulus is set to start directly from the matlab program when video scenes are projected on the second screen (i.e. projector screen or HMD). Some measurement program features are setting the length of measurement, the length of stimulation, choosing concrete stimulation, saving the name and age of patient and as well as analyzing typical (post-measurement) posturographic parameters such as line integral (length of trajectory), RMS parameter, velocities [6] and FFT. Program during measurement is depicted in Fig.1

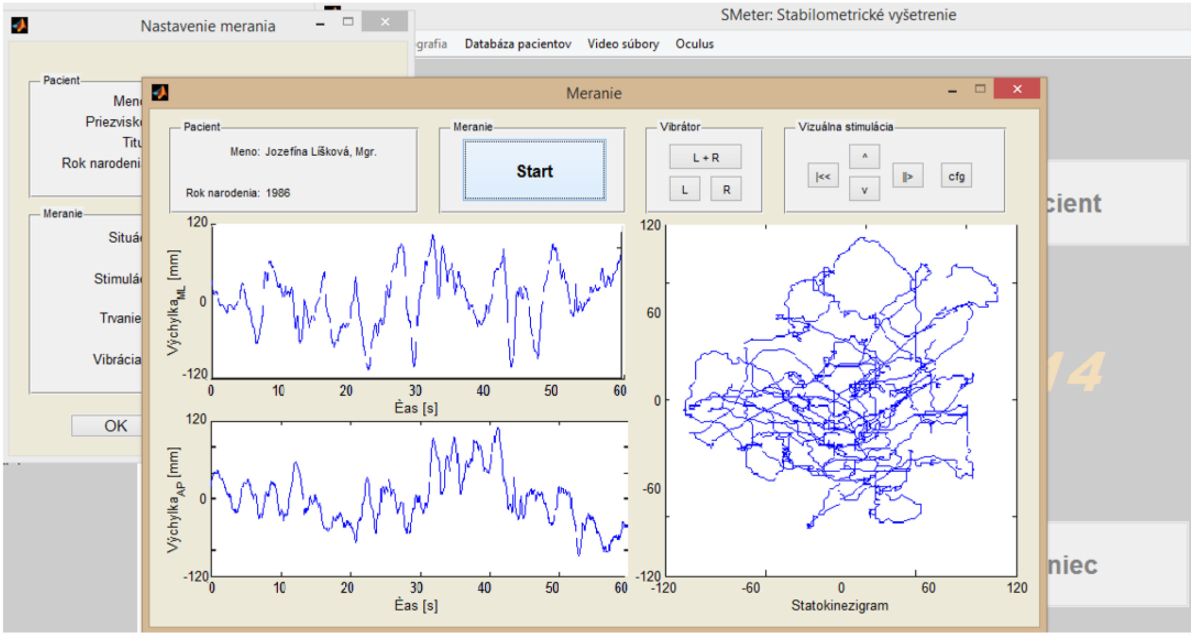

Figure 1. We developed Matlab based program that measure, acquire, analyze data as well as control visual stimulation – starts and stops it at the proper time

3 Image preparation for HMD device

We have used a method for converting the video frames for a „classical“ screen projection to the video frames for HMD devices. In the latter case, a field of the view is narrowed and the display is in the close proximity of patient eye. Due to that fact, image has to be particularly converted. We have used Oculus Rift for delivering visual stimulus. It is a new emerging trend in HMD technology. Oculus lenses have a pincushion distortion which is compensated with the predistortion of the image. This distortion has to be inverse – barrel distortion. Distortion and its correction is usually modeled with non-linear function – polynomial, rational function as well as a goniometric and logaritmic function.

We consider that the lenses are symmetrical. A distortion is characterized in relation to the point called center of distortion (COD) – itersept of the lens optical axis and image plane. (Fig. 2 a) Let P be a point in the undistored image and r is the distance in image plane from COD to P, then due to the distortion the distance is

$$r' = r.\,g_{dist}(r) \tag{1}$$

where distortion is charactarized by function g_{dist}. If (COD_x, COD_y) are the coordinates of the COD in the Cartesian system, then any point with coordinates (x_{in},y_{in}) is mapped do to point (x_{out},y_{out}) according to

$$\begin{aligned} x_{out} &= COD_x + (x_{in} - COD_x)\, g_{dist}(r) \\ y_{out} &= COD_y + (y_{in} - COD_y)\, g_{dist}(r) \end{aligned} \tag{2}$$

where r is distance from (x_{in}, y_{in}) to (COD_x, COD_y)

$$r = \|(x_{in}, y_{in}) - (COD_x, COD_y)\| = \sqrt{(x_{in} - COD_x)^2 + (y_{in} - COD_y)^2} \tag{3}$$

In case of barrel predistortion where $g_{dist} < 1$, the image displayed on the whole display screen (Fig 2. b) is transformed to a smaller image as depicted in (Fig 2. c). In this case, HMD field of view is not used effectively and the image is resized (Fig 2. d) so that image area is touching the edge of the screen.

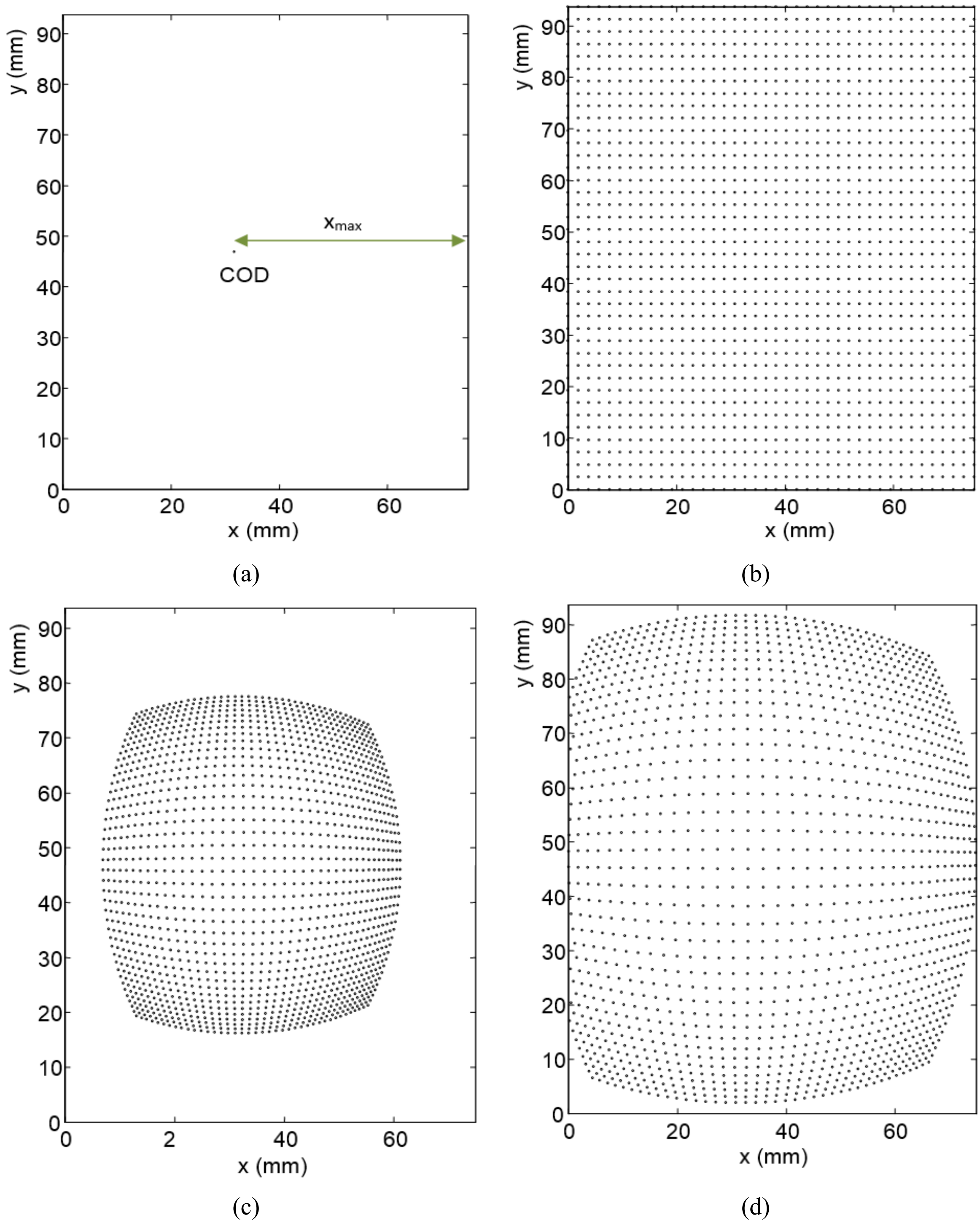

Figure 2 a) For description of COD and consecutive image transformation (b-d) needed for HMD devices.

As a distortion function g_{dist} we considered multiple options:

$$g_{dist}(r) = 1 + a_1 r^2 \tag{4a}$$

$$g_{dist}(r) = 1 + a_1 r^2 + a_2 r^4 \tag{4b}$$

$$g_{dist}(r) = \frac{1}{1 - a_1 r^2} \tag{4c}$$

$$g_{dist}(r) = \frac{1}{a.r}\,\mathrm{atan}(a.r) \tag{4d}$$

Function 4a does not allow demanding steepness, problem with 4b is that two coeficients need to be adjusted. Steeper characteristic can be achieved with 4c with setting one parameter, but function become decreasing for higher values of *r*, which leads to unwanted artefacts in image distortion – image was flipped in the corners. Empirically, the best was 4d, where distortion is provided with inverse tangent and is controlled with parameter *a* which we recommend to set around 1.5.

Resizing the image changes visual perception of the video scenes comparing to the reality and comparing to the video scenes delivered with the projetor screen. Therefore, it is needed to change „zoom“ of the virtual camera before predistortion is applied i.e. change the field of the view (FOV):

$$FOV' = 2\,\mathrm{atan}\left(s.\tan\left(\frac{FOV}{2}\right)\right) \tag{5}$$

where s is a resize factor defined as

$$s = \frac{1}{g(x_{max})} \tag{6}$$

Another thing that have to be considered is question of the stereovision. Image made for one eye is not centered in the screen of HMD. Optical axis is shifted accordingly depending on the eye distance and with that FOV becomes asymmetric. This situation is usually not suported in the most rendering programs. We used freeware program called InstantReality framework, which can be controlled from Matlab via web interface. This was the reason we used this alternative as it can be fully automated. For example, distortion in IntantReality framework can be modeified in the node *DistortionDisplayFilter.* Instantreality framework version 2.3 does not correctly support displaying for Oculus Rift – implementation of *StereoViewModifier* (with parameters *ZeroParallax distance* and *Eye Separation distance*) is not usable for Oculus Rift in this version. In version 2.4.0 a change was reportedly made. In version 2.3 shift of the optical axis was made by setting other nodes, namely *MatrixViewModifier* and *TileViewModifier*.

Images for each eye have to be made. This is done for every frame in the video scene. Example of completed video frame is shown in Fig. 3.

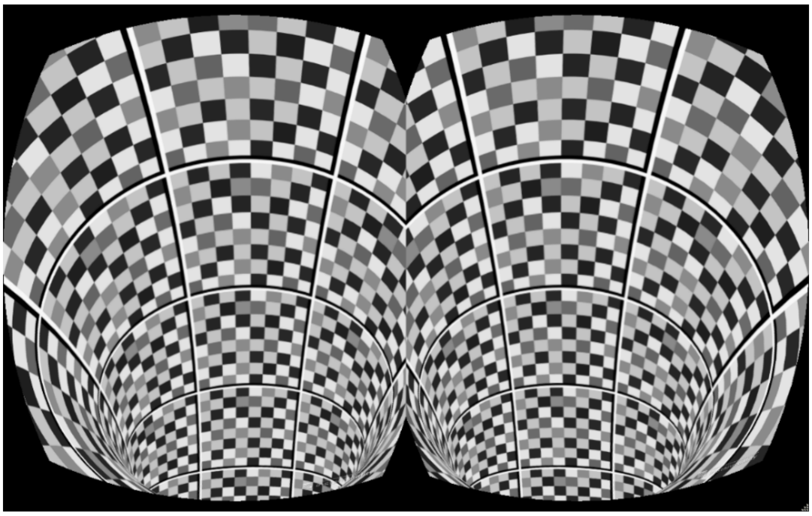

Figure 3 Example of completed video frame - a frame that has undergone every needed transformation as described above.

4 Conclusions

We have decribed a complete process of creating video scenes suitable for HMD devices with respect to HMD device we used – Oculus Rift. However, this process is universal for every similiar HMD device. We are planning to use the video scenes created for Oculus Rift as a visual stimulus in posturography. It may be rather inexpensive method for delivering visual stimulus comparing to methods like CNAVE, NAVE, BNAVE, or even like displaying on the projecting screen with a projector. We are planning to compare inlfuence on posturographic parameters from the point of view on the delivering technology – projector and proecting screen and HMD devices. For that reason comparable video scenes for each technology were developed. This process is also described. Every image manipulation is controlled from Matlab environment for the sake of automation. Matlab controls instantreality framework where images are created.

The program is developed in Matlab. The program controls and acquire data from DAQ device NI USB 6008 which measure center of pressure – signal that contains human body swaying.

Acknowledgement

The work has been supported by research grant VEGA 1/0921/13, VEGA No. 1/0664/14, IMMKSP(STU 2014), KEGA 022STU-4/2014

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Tomáš Lukáč
tomas.lukac@stuba.sk

Oldřich Ondráček
oldrich.ondracek@stuba.sk

Jozef Púčik
jozef.pucik@stuba.sk