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Realism Score for Immersive Virtual Reality Systems and Driving Simulators

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Abstract - *Traditional 2D or 3D quality assessment methods are not sufficient to assess the realism of the outputs of a simulator/immersive virtual reality system. We propose an assessment method based on a scoring system through a new approach. The objective of this paper is to propose a score scale for any simulator or immersive display system that would represent how close to the human visual system the signals that are sent through the display are. Weighted items considered are contrast, acuity, frames per seconds, brightness, field of view and the number of color available.*

Keywords: *Virtual Reality, Realism Assessment, Objective Scoring, Human Visual System*

Introduction

Defining realism can be done by choosing one acceptations out of the different meanings that the word can have in VR [Fuc03] : realistic looking, realistic construction (models), physiologic realism (vision and perception), psychological realism (acceptation) and presence. The definition that was of interest for this study is the one based on realistic physiological parameters (i.e. physiological models of perception of the scene that are matching with the human visual system (HVS) behavior).

Presently, there already exists numerous methods for quality assessment of 2D images/video streams and 3D objective and subjective image quality assessment. Different reviews were done earlier [Moo13b, Moo13a]. But these techniques are not sufficient to deal with quantifying realism : a new method has to be designed. Quality assessment is based on the comparison of a source file with the same file that went through a transformation loop (like video encoding) [Ca04] while VR images are generated in real˘ time.

We hence wanted to develop a score scale, a grade system, that would be transposed from physiological criteria.

Work Hypotheses

Though the grading system is to be usable in any situation and in any simulator, several hypotheses or guiding rules were made.

First, we divide the different items of the grading system in two types : those for which a behavioral model is already known in the literature, and those for which we found a number of distinct values. The scale can be summarized this way :

— The grade of 0 is given to any value beyond which the graded item is not working, the value is not acceptable.

— The grade of 80 is given to any value which is the standard performance of a perfect observer.

— The grade of 100 is given to any value that is the maximum of the HVS, beyond which the body cannot, physically, perceive differences. All the intermediate values are not always assigned, depending on the values found in the literature.

Scoring System Proposition

The objective of the study is to have, for any simulator or immersive display system, a score between 0 and 100 that would represent how close to the human visual system the signals that are sent through the display are. It aims to be independent of the content of the virtual scene and independent of the viewer. It is made of 7 weighted items (see as follow) and completed by non-physiological limiting factors in a second time (such as uniformity throughout the simulator). Weighting (based on use-cases) and limiting factors will be addressed later.

Contrast

Contrast is the difference in brightness/color between the light and the dark parts of an image, of an object.

Though there exists several local or global definitions of contrast, such as Michelson Weber or Peli, none of them are suitable for complex images [Win99b, Win99a]. We hence fall back on practical values and measurement, such as ANSI contrast (also called simultaneous contrast). The ANSI contrast shows contrast in an approximation of a running simulation. It is measured for a single screen from a 16 black and white squares pattern. ANSI contrast must be generalized to the whole simulator and hence become System Contrast.

Acuity (Mono)

Monoscopic acuity is the accuracy of the human eye, its definition. This concept can be directly linked with the size of the pixels in the driving simulators or immersive displays : the smaller the pixel the more accurate the image.

Usually, it is said that the HVS has an acuity between 30" of arc and 2' of arc, with a practical mean of 1' of arc [Fuc03]. Those values can be, in photopic conditions, refined per task [Gro08].

Acuity (Stereo)

Stereo acuity is the ability of the Human Visual System to perceive the difference in depth between two planes, at a given distance. It is well known and described in literature. Stereo acuity follows a geometric pattern that is demonstrated in [Fuc03, Gro08]. The generally accepted model is $\Delta r = 0.001r^2$. Where Δr is the theoretical minimum observable difference in depth (in millimeters) and r the distance of observation (in meters).

Frame Per Second (FPS)

First, motion perception starts at 16 FPS. Under this threshold, no movement is perceived, only a suite of distinct images. Secondly, Driscoll et al. [dri78] determined the frequency beyond which flickering would disappear. Critical flicker frequency, for any luminance and riple ratio, is of 70Hz.

Ventral and dorsal pathways is the main theory on how the brain is dealing with visual data. The two pathways are allegedly running at respectively 25 and 200Hz, which is correlated by the fact that one is fast and the other slow, and by the number of cortexes the pathways run through [D'h11] ; but no real scientific proven values were found yet.

Color Space Covering

CIE XYZ was established in 1931 as the a color space representing all the colors that a human eye can see. All the different systems use a fraction of this color space : gamut. Gamut size depends of the three primary colors chosen. Empirically, acceptation begins at Adobe RGB, which covers 52.1% of the CIE space.

Brightness

The ANSI contrast is a useful practical definition of contrast. But ANSI is not a fully sufficient measurement : a 10000 nits white and a 10 nits black will give the same contrast as a 100 nits white and a 0.1 black.

Based on [Gro08], The eye can accept a very large radiance from 10^{-6} to $10^{5} Cd/m^2$. Plus, the stimulus of accommodation occurs only above the luminance value of $0.01 Cd/m^2$. As it is always harder to achieve because of hardware issues and of the surrounding lights that pollutes it, the black level is to serve as the reference for the brightness level.

Field of View

Field of view (FOV) is defined as the portion of space that one can see at a given time, without moving the head.

Some of the most common values can be found in [Dev04]. On the azimuth angle, with both eyes, a standard human being is able to see from 170 to 190 degrees ; while on the elevation angle it is only 130 to 145 degrees. Within the azimuth angle, 120 degrees (only) are capable of binocular vision. Reading can be only achieved in a cone of 20 degrees while patterns recognition needs 40 degrees and color discrimination 60 degrees.

Final Score Model

Finally, a final realism score model is proposed. It is obtained through the sum of all the previously seen items, here referred as σ_i, times the correlated coefficients, here referred as λ_i ; everything being divided by the sum of the coefficients to have the score value fit between 0 and 100. Score is given by the following equation : $S = \frac{1}{\sum_{i=1}^{n} \lambda_i} \sum_{i=1}^{n} (\lambda_i . \sigma_i)$.

Conclusion

We propose a scoring system based on a new approach. Such a score system could be useful for quantifying the correlation between a simulator and the HVS, which would lead to the ability, based on the simulators' perks, to choose on which simulator carry out an experiment and to put the results of experiments in perspective. On a more industrial point of view, this scoring system could help in building the specs of new simulators.

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