APPLICATION OF A DEFORMABLE MIRROR TO A TIME-MULTIPLIED FIXED-VIEWPOINT VOLUMETRIC VIRTUAL REALITY SYSTEM

Author: David Amat Olóndriz
Supervisors: Meritxell Vilaseca Ricart, Carles Otero Molins

1. INTRODUCTION

The majority of 3-D virtual reality systems lack the ability to render scenes without providing appropriate depth cues and forcing the viewer to decouple the natural convergence-accommodation relationship. In this project, a recent technique based on time-multiplexed fixed-viewpoint volumetric systems has been considered as the potential alternative for inefficient virtual reality systems. The methodology required to create multiple focal planes is put into practice by means of an optical setup and the subsequent validation for the results obtained. A micro-electro-mechanical (MEMS) deformable mirror has been selected as the optical element responsible for rendering each frame from a high-frequency display to its respective focal plane. This procedure when done in a swift way, creates a stack of superimposed focal planes that are seen by the viewer as a real 3-D scene without breaking the convergence-accommodation relation.

2. OPTICAL SETUP

The optical setup implemented is similar to the one presented by Hu and Hua [1]. The optical elements are: a near-infrared laser (780 nm), a telescope providing a magnification of 2, a beamsplitter, a Hartmann-Shack sensor, trial lenses and a deformable mirror.

3. MEMs DEFORMABLE MIRROR

Boston Micromachines Corporation’s mirror formed by 144 actuators (square of 12x12) with a maximum voltage of 210V leading to a deflection of 3.5 μm inwards as seen in Figure 3. Frequency of transition between two different spherical forms: 3 kHz. The optical power in dioptres (D) of a mirror can be obtained by knowing the maximum deflection of the centre (c) and a pupil diameter (D) that fits into the mirror’s active region:

\[
P = \frac{16 \cdot c^2}{D^2}
\]

4. SPHERICAL SHAPES

When creating a spherical wavefront (WF), Zernike polynomials must be considered, specifically the defocus one, leading to a two-dimensional function defined within a circular domain with the deflection of any point \((x,y)\) defined by:

\[
WF(x,y) = \sqrt{Z^2 - (2 \cdot \frac{x^2 + y^2}{PR^2} - 1)}
\]

\[
M = \sqrt{\frac{Z^2}{PR^2}} \quad \text{Sph} = M \cdot \text{Cyl}
\]

From a desired Sph value in dioptres (D), and considering null astigmatism (Cyl=0) for a pure defocus shape, the mean spherical value (M) can be obtained. Then, by choosing the appropriate pupil radius (PR), which will be given by the deformable mirror’s active region, the defocus coefficient \((Z^2)\) is retrieved from Eq. 3, leading to an actuator map where each actuator centre \((x',y')\) has a definite deflection according to Eq. 2.

5. HARTMANN-SHACK SENSOR

Figure 2. Optical setup. Blue lines denote light’s path.

Figure 3. MEMs deformable mirror from Boston Micromachines Corporation.

6. EXPERIMENTAL RESULTS

Deflections obtained with Eq. 2 can be converted to voltages, which will be sent to the mirror. The curve relating deflections with voltages is provided by Boston Micromachines Corporation and a polynomial fit must be performed to obtain the relation between both variables:

\[
V = \frac{(P \cdot c^2)}{16} = \frac{(c^2)}{PR^2}
\]

From the Sph value given by the analysis software in Figure 5 it can be shown how the obtained Sph deviates from the desired Sph, see as the input of our script to control the mirror after a calibration procedure:

\[
\text{Measured D} = Sph \times \text{Cyl}
\]

\[
\text{Desired D} = \frac{s}{\text{Cyl}}
\]

7. CONCLUSIONS

The presented work has gone through the main specifications that should be taken into account when selecting a deformable mirror for 3-D imagery purposes, as well as to present a simple setup to validate each spherical shape by means of aberrometry (Hartmann-Shack technique). Additionally, it has given an insight into how to simulate a defocus wavefront. It should be noted the importance of computer programming (Matlab®) to automate the process for any desired spherical shape. Finally, in spite of the difficulties encountered with the mirror, I succeeded in accomplishing defocus wavefronts for any desired dioptric power, obtaining nearly the same optical power from the mirror as the desired one.

REFERENCES