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LOSS OF THE EUCLIDEAN PERCEPTION OF SPACE IN UNDERWATER SCENES

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Abstract: *The experience observing objects in air or under the water indicate that changes in the appreciation of distances and sizes take place. Several theoretical models exist in which the appreciation of the space is justified. One of the simplifications, common in these models, is that they do not consider that every flat interface between two optical media suffers of spherical aberration. In this work objective observations are presented – using a digital camera– of scenes in air and submerged in water at different depths and photographed from different inclinations respect to the normal to the interface air/water. The analysis of the obtained results permits to verify that indeed the spherical aberration must be considered, which implies the loss of the Euclidean perception of the submerged space.*

1 INTRODUCTION

The experience observing objects in air or under the water indicates that changes in the appreciation of distances and sizes take place, as it is shown in Figure 1 where the scene composed by the three cylindrical tubes and the metallic rule are in air, and in Figure 2 where the scene is under the water. The observation in Figure 1 is indeed Euclidean, while in Figure 2 seems to be definetely non Euclidean.

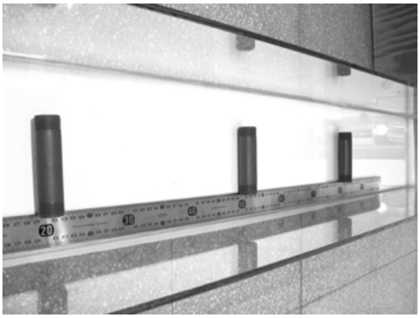

Figure 1: Scene in air.

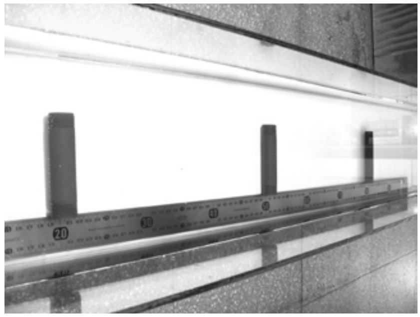

Figure 2: Submerged scene.

Its explanation have generated controversies due to the existence of several theoretical models which try to describe the perception of space (Ross, H.E. & Nawaz S., 2003). However, we have found in several of these models that the comparisons between the observation in air and under the water are based exclusively in the application of Snell Law of Refraction in paraxial conditions. This approach does not consider that every flat interface between two optical media –as air/water– suffers of spherical aberration (SA). In general, the amount of SA increases with the angle determined by the line of sight respect to the normal of the interface air/water.

Consider an object submerged in water being observed from the air in the direction of a paraxial ray of light, that is a ray inclined to the normal to the interface air/ water by a very small angle –the left part in Figure 3–, and compare this situation with that far from the paraxial case –the right part in Figure 3–. The SA of such interface produces the image of the object to appear from the air at a depth and with a transversal size proportional to $\tan^2\alpha$ and $\tan^3\alpha$ respectively. (Smith, G. & Atchison, D.A., pp. 114-116, 1997). It is this discrepancy in the appreciation of distances to objects and their respective sizes due to SA which introduces a non Euclidean geometry in the underwater vision.

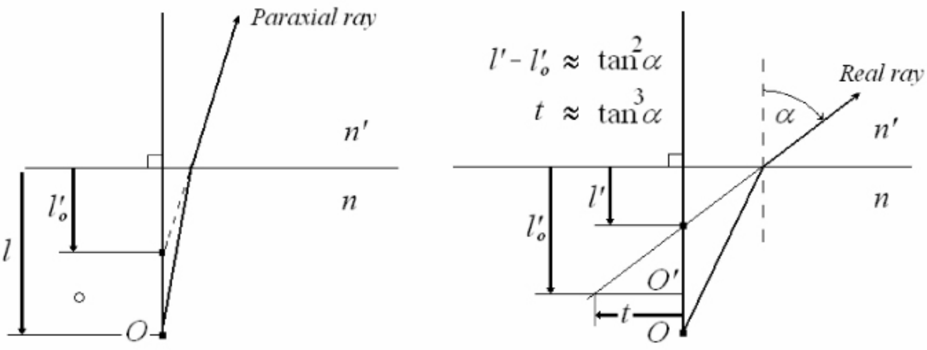

Figure 3

2 EXPERIMENTAL SETUP

In order to make an experimental verifications of the effect of the SA of the flat interface air/water in the appreciation of the space we designed a simple installation to observe an object in air and submerged in water at several distances respect to the interface air/water. The object is a plastic card of 9 cm wide and 15 cm high.

The card was submerged in a container of 120 cm long until half of its height, thus allowing simultaneously making water and air observations.

We have despised the effect of the glass wall of the container, a plane-parallel window, which affects practically in a similar way in both observations.

We made a series of observations with the card centered with the optical axis of the camera, “centered series”, and another one with the displaced card laterally, “displaced series”, as it is shown in Figure 4.

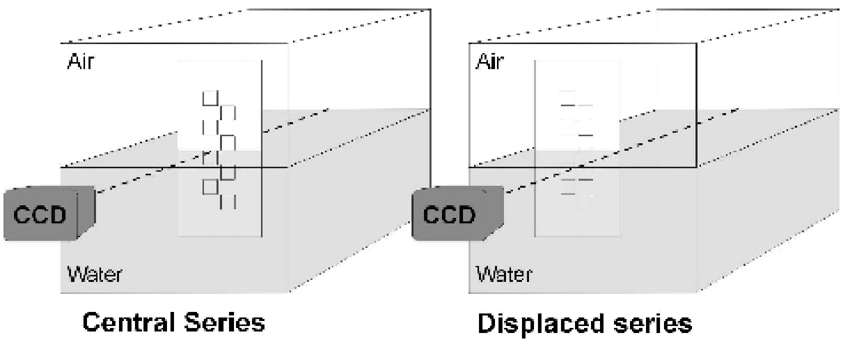

Figure 4: Scheme of the experimental device used for the measurements.

Each series consisted of observations of the card at fourteen different depths respect to the observation wall of the container.

With the purpose of obtaining objective results, we used a commercial digital camera located in the air 40 cm in front of this wall.

3 RESULTS

In the images taken with the digital camera the width of the card in air and in water were measured, in the proximity of the water level; results are represented in Figure 5.

In Figure 6 the ratios between the measurements of the width between the borders of the card in the air and underwater are represented according to different depths; besides, they are compared with the paraxial condition of observation.

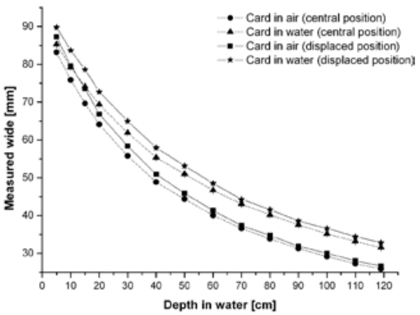

Figure 5: Measurements of the width of the cards image underwater and in air at different depths.

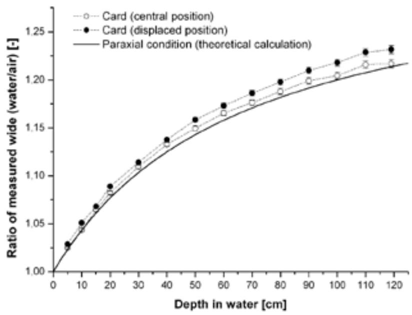

Figure 6: Ratio between measurements ofthe width of the image of the card underwater and in air at different depths.

4 CONCLUSIONS

The experience observing objects in air or under the water indicate that changes in the appreciation of distances and sizes take place. In this work objective observations were presented –using a digital camera– of scenes in air and submerged in water at different depths and photographed from different inclinations respect to the normal to the interface air/water, and the results enables verify that indeed the SA must be considered, which implies the loss of the Euclidean perception of the submerged space, as it was shown in Figures 1 and 2.

References

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Smith, G. & Atchison, D.A. (1997) *"The eyes and visual optical instruments"*. Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, United Kingdom, pp 114-116.