Computational Fourier Domain Synthetic Aperture Integral Imaging

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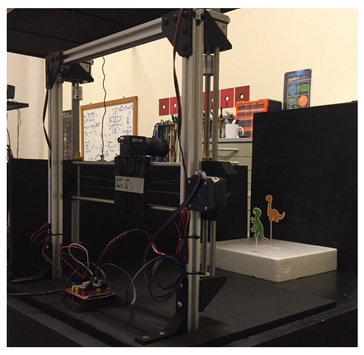
Introduction

Integral imaging with synthetic aperture allows to capture multiple perspectives of a three-dimensional scene [1, 2]. The proposed work includes an open-source platform based experimental set-up that allows to create an Integral Image that can be used to reconstruct the three-dimensional scene refocused at any given depth or refocusing at different depths simultaneously in the same reconstructed image.

Contribution

The open-source platform based experimental set-up allows to translate a single camera in a vertical plane [3] in order to capture different perspectives [4] (elemental images) of a three-dimensional scene, constituting an integral image. Under this configuration, the integral image of an object is subject to a periodic pattern (2D Dirac Comb) with a period that depends on the object's depth, this can be exploited to implement Fourier Domain filtering [5].
In order to compensate aqcuisition errors caused by mechanical movement of the camera the Integral Image had to be rectified by adjusting it to an optimal regular net. With the rectified Integral Image it is possible to compute its Fourier Transform to multiply it by the Fourier 2D Dirac Comb with the period related to the depth to be reconstructed, the scene refocused at that depth is obtained by taking the Inverse Fourier Transform of that multiplication.



Conclusions

It is possible to reconstruct the scene as focusing at different depths and perform Fourier filtering to improve the results. As future work, we intend to explore simultaneous focusing at non consecutive planes and all-in-focus reconstruction.

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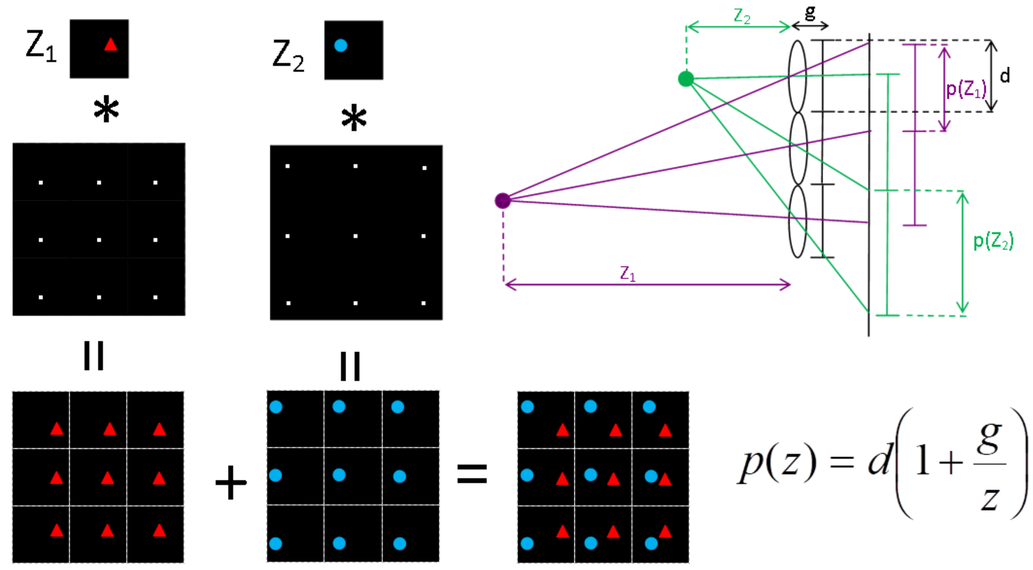
Method



$$p(z) = d\left(1 + \frac{g}{z}\right)$$

- Figure modified from [5] ilustrating how the Integral Image is formed.
- Distance between sensor and lens (f), diameter of the lens (d), depth (z).
- The above equation shows the relation between depth and periodic pattern of an object.
- The closer the object to the lens, the bigger the period.

Results

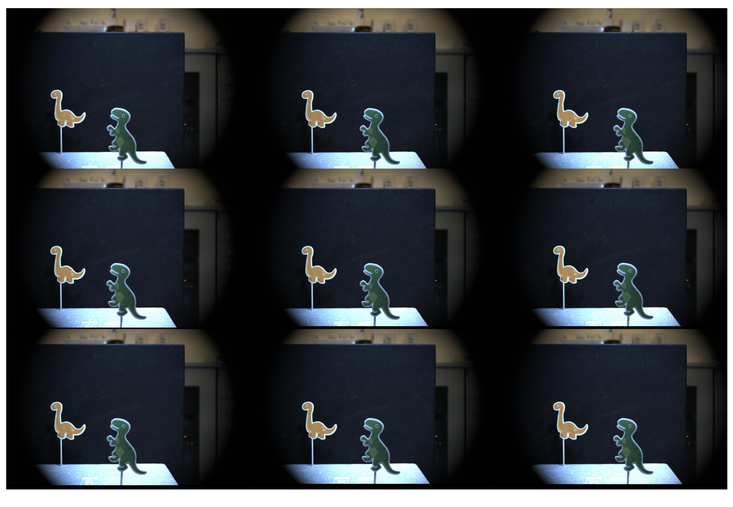


Figure 1: Integral Image

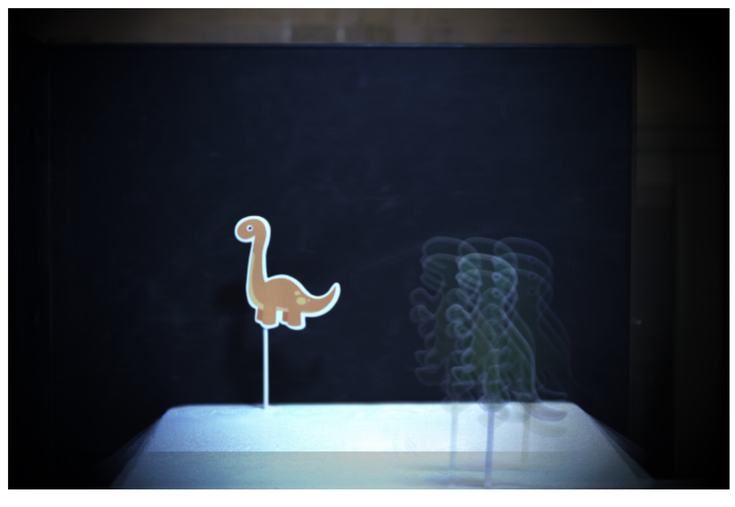


Figure 2: Re-focus without Fourier filtering

Figure 3: Re-focus with Fourier filtering

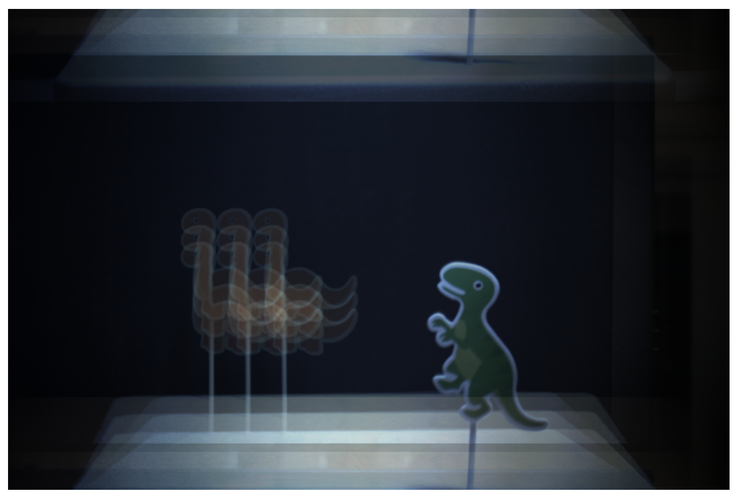


Figure 4: Re-focus with Fourier filtering

Bibliography

[1] Saavedra, G., Martínez-Cuenca, R., Martínez-Corral, M., Navarro, H., Daneshpanah, M., Javidi, B. (2008). Digital slicing of 3D scenes by Fourier filtering of integral images. Optics express, 16(22), 17154-17160.
[2] Tian, F., Yang, W. (2022). Learned lensless 3D camera. Optics Express, 30(19), 34479-34496.
[3] Campbell, T., Jones, J. F. (2020). Design and implementation of a low cost, modular, adaptable and open-source XYZ positioning system for neurophysiology. HardwareX, 7, e00098.
[4] Alonso, J. R., Fernández, A., Ferrari, J. A. (2016). Reconstruction of perspective shifts and refocusing of a three-dimensional scene from a multi-focus image stack. Applied optics, 55(9), 2380-2386.
[5] Llavador, A., Sánchez-Ortiga, E., Saavedra, G., Javidi, B., Martínez-Corral, M. (2015). Free-depths reconstruction with synthetic impulse response in integral imaging. Optics Express, 23(23), 30127-30135.