Invited Paper

Fully-programmable display parameters in integral imaging by smart pseudoscopic-to-orthoscopic conversion

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ABSTRACT

Previously, we reported a digital technique for formation of real, non-distorted, orthoscopic integral images by direct pickup. However the technique was constrained to the case of symmetric image capture and display systems. Here, we report a more general algorithm which allows the pseudoscopic to orthoscopic transformation with full control over the display parameters so that one can generates a set of synthetic elemental images that suits the characteristics of the Integral-Imaging monitor and permits control over the depth and size of the reconstructed 3D scene.

Key words: Integral imaging, 3D imaging display, digital processing

Stereoscopic or auto-stereoscopic monitors usually produce visual fatigue in the audience due to the convergence-accommodation conflict. An attractive alternative to these techniques is the so-called Integral Photography (or Integral Imaging –InI), initially proposed by Lippmann in 1908 [1], and resurrected about two decades ago due to the fast development of electronic matrix sensors and displays. The Lippmann idea was that one can store the 3D image of an object by taking many 2D photos of it, but from different positions. Of course, this can be easily done by using a micro lens array (MLA) as the camera lens. Anyway, the key of his proposal was the fact that each photo, or elemental image, stores the information of a different perspective of the object. When this info is projected onto a 2D display placed in front of an array of micro lenses, the different perspectives are integrated as a 3D image. To understand this integration, one must note that any pixel of the display generates a conical ray-bundle when it passes through the microlens array. And it is, precisely, the intersection of many ray-bundles which produces the local concentration of light-density that permits the reconstruction of the object. This reconstructed scene is perceived as 3D by the observer, whatever his/her position. Since an InI monitor truly reconstructs the 3D scene, the observation is produced without special goggles, with full parallax and absent of any visual fatigue [2].

One important problem to solve when intending to project the integral images in a monitor is the structural differences between the capture setup and the display monitor. To tackle this, we developed an algorithm, denoted here as the Smart Pseudoscopic-to-Orthoscopic Conversion (SPOC) that permits the calculation of new sets of synthetic integral images that are fully adapted to the display monitor characteristics. Specifically, this global pixel-mapping al-

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gorithm permits us to select the display parameters such as the pitch, focal length and size of the MLA, the depth position and size of the reconstructed images, and even the geometry of the MLA [3].

The algorithm is the result of the application in cascade of three processes: the simulated display, the virtual capture and the homogeneous scaling. In the first step the captured integral image is used as the input of the algorithm. The virtual capture is simulated to occur through an array of pinholes. The position of the array, the pitch, the gap, and the number of pixels are assigned arbitrarily to match the monitor characteristics. Finally, the homogeneous scaling is intended to adapt the size of the integral imaged to the InI monitor.

To demonstrate the utility of the algorithm, we generated an integral image ready to be displayed in a monitor whose parameters are very different from the ones used in the capture. For the capture of the elemental images, we prepared over a black background a 3D scene shown in Fig. 1, and picked up the elemental images with only one digital camera that was mechanically translated.

Fig. 1 Scheme of the experimental setup used for the capture of the integral image of the 3D scene.

In Fig. 2 we show the recorded integral image, which was composed by 31x21 elemental images with 51x51 pixels each.

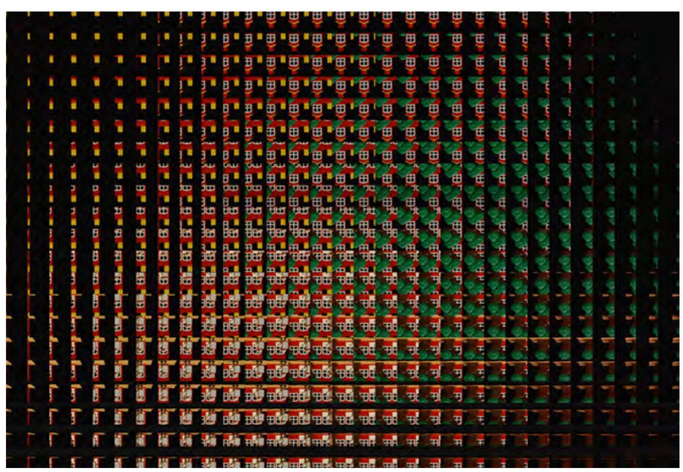

Fig. 2 Integral image obtained experimentally. This image is the input for the SPOC algorithm.

Since our aim was to produce a synthetic integral image for being displayed in a commercial MP4 device consisting in a matrix display with 900x600 pixels of 79.0 μm each, we calculated a matrix of 75x50 elemental images with 12x12 pixels each. In Fig. 3 we show the calculated integral image which, besides, is prepared for displaying a real, orthoscopic 3D image.

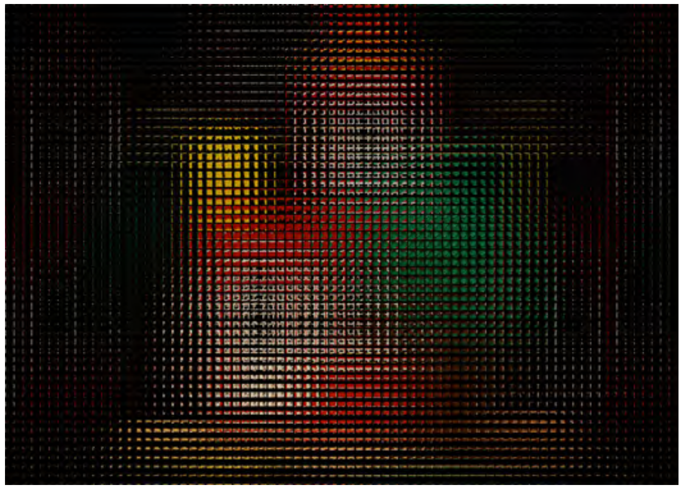

Fig. 3 Collection of 75x25 synthetic elemental images calculated with the SPOC algorithm, and therefore ready to produce a real orthoscopic image.

Finally, we displayed the synthetic integral image in the matrix display of the MP4 device. Then we placed a microlens array, in perfect alignment with the elemental images. In order to avoid braiding effect, we took care that the distance between the screen and the microlenses was equal to their focal length [4]. As we show in the Fig .4 (and more clearly in the Movie) the display produced an orthoscopic floating 3D reconstruction of the 3 scene that can be observed with full parallax.

CONCLUSIONS

We have demonstrated the SPOC algorithm which allows full control over the optical display parameters in InI monitors. Specifically, we have shown that from a given collection of elemental images, one can create a new set of SEIs ready to be displayed in an InI monitor in which the pitch, the microlenses focal length, the number of pixels per elemental cell, the depth position of the reference plane, and even the grid geometry of the MLA can be selected to fit the conditions of the display architecture.

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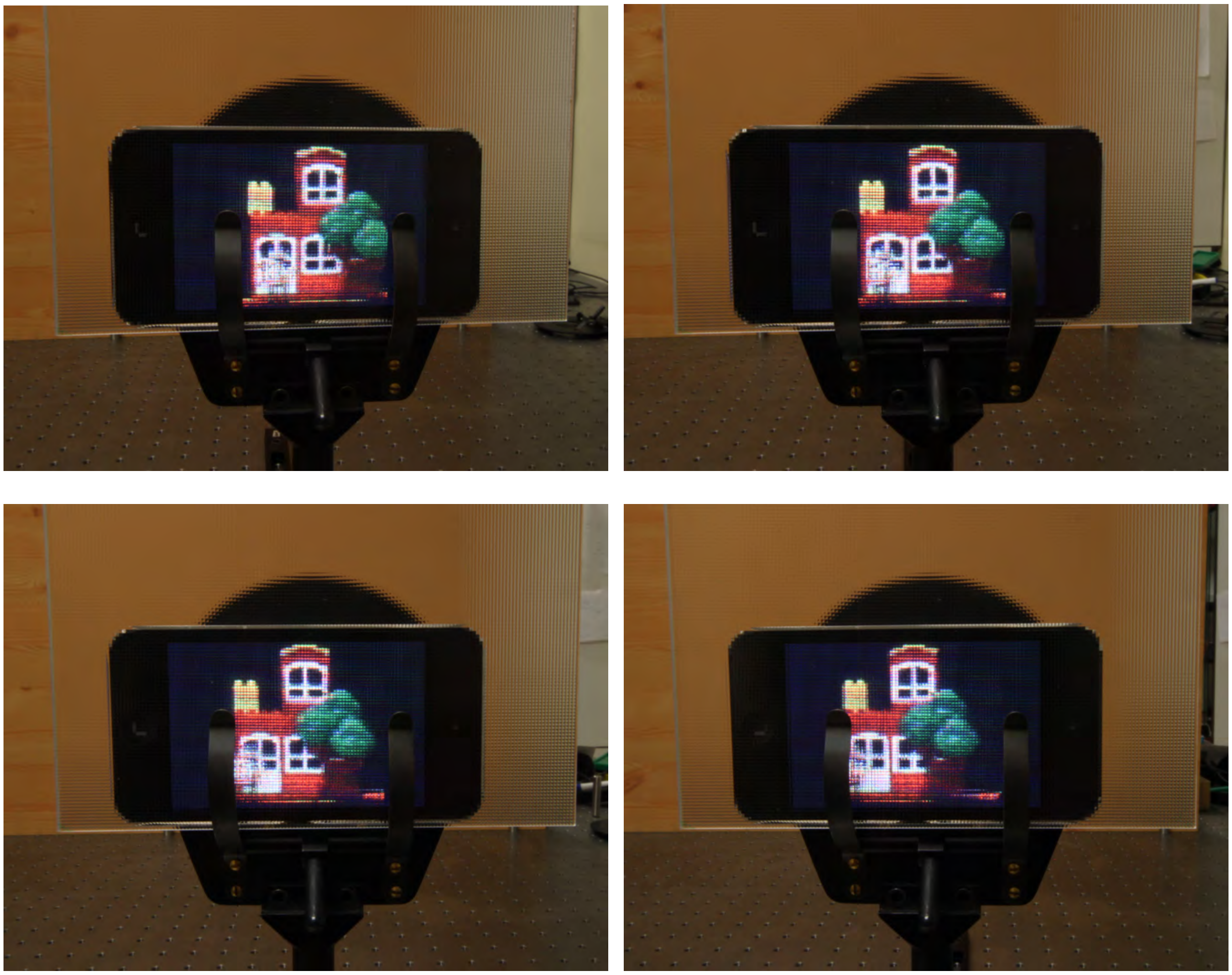

Fig. 4 Four views of the reconstruction of the orthoscopic, floating 3D image through a MP4 device.