Computational Acquisition and Display Technologies for Light Fields

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As a framework of describing 3-D visual information, the concept of light field (LF) was developed in early 1990s. An LF describes all the light-rays originating from a target scene and proceeding to a limited range of directions. Thus, in theory, the LF can reproduce all possible 3-D appearances of the target scene within the limited directional range. This framework has been used for many applications such as depth estimation, object recognition, photo-realistic view synthesis, and 3-D displays.

From the viewpoint of engineering, an LF is often represented as a set of rectified multi-view images consisting of tens to hundreds of images, where the viewpoint intervals among them are extremely small (less than centimeters). This leads to the fact that although an LF has a huge amount of data, it is highly redundant. Understandably, this redundancy can be used to improve the efficiency in processing an LF. In this talk, I will mention how we can enhance the efficiency of LF acquisition and 3-D display, where computational approaches are adopted to exploit the inherent redundancy of the LF.

I will first mention LF acquisition using a coded aperture camera, where the aperture plane can take various transmittance patterns to encode the directional information of the light-rays. In other words, an image captured with this camera can be regarded a compressed representation of the LF inside the camera. As mentioned above, the LF has much inherent redundancy. Accordingly, it is expected that if the encoding scheme is well designed, we can reconstruct the entire LF, e.g., consisting of 5 by 5 or 8 by 8 images, only from a few images captured by this camera. To achieve this, we need to seek the optimal transmittance patterns and the corresponding computational reconstruction algorithm. I will introduce our work [1] on this point along with the recent trends in computational acquisition of light fields.

I will then introduce one of the computational LF displays that consists of a few light-attenuating layers, such as LCD panels, stacked in front of a backlight. The transmittance (attenuation ratio) patterns for them are computationally optimized to reproduce a target LF as accurately as possible. An important aspect with this display is that the LF is represented in a compressed manner; tens to hundreds of images can be reproduced from only a few layers without sacrificing the spatial resolution. This tremendous compression is achievable because the LF is so much redundant. I will introduce our work [2, 3] on this display including theoretical analyses, algorithm, and hardware development in the context of recent advances in LF display technologies.

[1] Y. Yagi, K. Takahashi, T. Fujii, T. Sonoda, H. Nagahara: "Designing Coded Aperture Camera Based on PCA and NMF for Light Field Acquisition", accepted to IEICE Transactions on Information and Systems (2018.9).

[2] Y. Kobayashi, S. Kondo, K. Takahashi, T. Fujii: “A 3-D Display Pipeline: Capture, Factorize, and Display the Light Field of a Real 3-D Scene”, ITE Transactions on Media Technology and Applications Vol. 5, No. 3, pp. 88–95, (2017)

[3] K. Takahashi, Y. Kobayashi, T. Fujii: “From Focal Stack to Tensor Light-Field Display”, IEEE Transactions on Image Processing, Vol. 27, No. 9, pp. 4571–4584, DOI: 10.1109/TIP.2018.2839263 (2018.9).