Extraction algorithm of light field information from multi-focus images

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Abstract— **Recently, demand for acquisition of 3D optical information using optical sensors in a 2D arrangement is rapidly increasing with development of computational processing devices and optical systems. Among various approaches, light field cameras are promising in acquiring 3D position and angle information of objects.**

Unlike the existing light field cameras using micro-lens arrays, our approach is firstly taking the images at different focal points and then extracting 4D light field information using the new unique algorithm developed in this study.

This new algorithm allows to extract the specific light field information originating from a specific single point source among the mixed light field information in the space without iteration typically required image processing. This new approach for extracting 4D light field information is not limited by point-spread-function (PSF).

I. Introduction

Line, plane, and volume light sources can be thought of as the sum of individual point light sources, and images taken by sensor arrays or cameras can be expressed as the sum of light emitted from multiple point light sources.

Measured light field information from a particular point source varies with its emission characteristics, interaction with other objects (e.g., obscuring opaque objects) in the middle of light propagation, and employed optical systems. This overall influence is commonly referred to point-spread-function (PSF).

Point light sources may be represented by shift-invariant PSFs as a function of distance from the source. Additionally, the images taken by the sensors may include noise terms due to air scattering, sensor dark current, etc. As a result, the images become obscure. The sole object information can be extracted from the measured image by deconvoluting out inevitably included PSF components and is called deconvolution imaging.

The algorithm developed in this study acquires 3D light source locations and shift-variant PSFs from images taken at different positions or multiple focal points, and is applicable to both light field and deconvolution imaging.

Without prior information and constraints on PSFs, light emitted or reflected from a particular location among mixed light fields is extracted by a non-iteration manner.

An optical system in which a lens system exists may also be described in the same manner, but for convenience of description, it will be described based on a sensor without any lens.

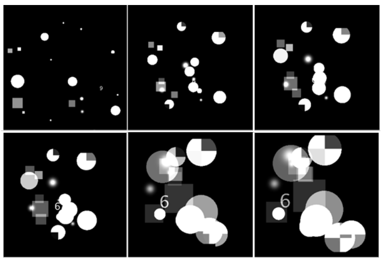
II. Result and Discussion

The basic optical system consists of n light sources and 2D sensor arrays located at m depths away from the light sources.

If the sensor exists at the position of the light source, the positions of each light source will be sufficiently measured by one single pixel of the sensor, but the PSF information disappears. As the sensor moves away from the position of the light sources, the PSF of each light source becomes diverse and overlapped. As a result, the information from the various light sources becomes mixed and indistinguishable.

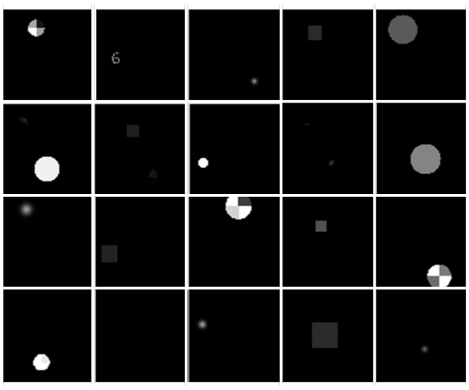
To obtain light field information or PSF emitting at a specific position L_0 among the mixed PSF information, it is assumed that all signals measured by sensors at m positions originate from L_0. Then, images at specific depth (Z') will be predicted through the measured signals.

Among the predicted signals at Z', the components emitted from L_0 are accurately predicted because they are emitted from L_0. But the components from light sources at different positions are not predicted correctly. And the components from the same location and brightness are emitted from L_0, and the moving components are from different light sources.



[Fig.1] Simulated images of 20 light sources emitted at random locations with different PSFs. Simulated at six depths by MATLAB.

Fig. 1 shows simulated images of 20 light sources at random positions with PSFs taken from the sensors at 6 different depths.



[Fig.2] Decomposed 20 light source information using the proposed algorithm without PSF information in advance.

Fig.2 shows the decomposed images of Fig.1 by the PSF of each light source using sensor depths and light source position information without prior PSF information. Using this, refocusing and observation position change are possible.

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