In Proceedings International Symposium on Microoptical Imaging and Projection
Fraunhofer IOF, Jena, 27-29. Nov. 2012 (MIPS2012), pp. 87-89
doi: 10.5281/zenodo.10950

PLENOPTIC IMAGE ACQUISITION AND PROCESSING

BERND JÄHNE
HCI, UNIVERSITY OF HEIDELBERG, GERMANY

The projection of a 3-D scene to a single 2-D image plane retrieves only very limited information. In general, neither the 3-D structure nor the optical properties of the observed objects can be estimated. This limitation can be related to a too sparse sampling of the plenoptic function. The plenoptic function is the starting point for a general theory of imaging. Some first research results beyond traditional imaging are shown. Analyzing the orientation of the plenoptic function as captured by plenoptic cameras results in surprisingly accurate depth information even from objects with specular object surfaces.

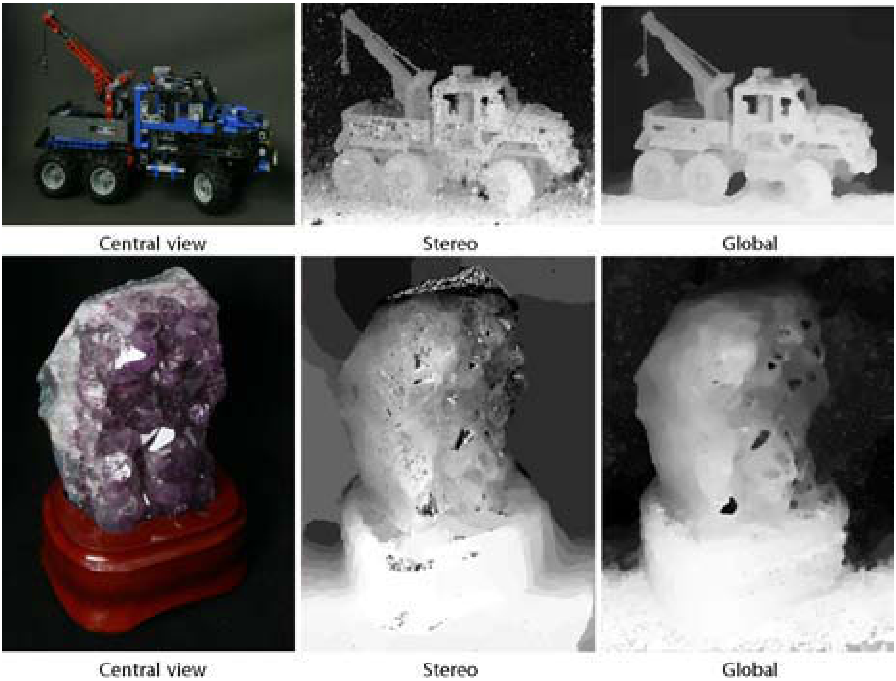
There is a well-known saying: "a picture is worth a thousand words". True. However, how much does a single two-dimensional image say about an observed three-dimensional scene? Not much.

There are some much regarded and some less regarded losses of information. By perspective projection of the 3-D space on a 2-D image plane, one coordinate is lost. The position in the image yields only the relation of object size to object distance. Thus both remain unknown as well as the orientation of surfaces. In the last two decades much research in computer vision and also in technical optics focused on techniques to capture depth from 3-D scenes with opaque objects. The situation is much more complex for a full volumetric reconstruction. Then a single projective imaging is not suitable at all but tomographic techniques are required.

A much less regarded loss of information is related to the radiometry of imaging. The irradiance at the image plane is unfortunately not directly related to the optical properties of the observed objects such as the reflection coefficient. The radiance of an object is a rather complex function of the direction and of the radiation received by the object surface, the direction of the surface element, its optical properties - which of need to be expressed by a bidirectional reflection distribution function (BRDF) or even more complex functions -, and the look direction of the camera. Thus the object irradiance at the image plane is not a direct feature for image processing. This is the elementary cause why it is so difficult to find robust object features for object segmentation and classification. Thus an image does not say much about the optical properties of an object. Even the color of an object at the image plane is not unique.

All these severe limitations result from the fact that we have captured just a single image from the scene. What if we would take images from all possible directions and illuminate the scene from all possible directions? Then we would gain a six-dimensional function, the light field or plenoptic function. A projective imaging with a pinhole camera is nothing else but a 2-D hyperspace of the plenoptic function, a real camera integrates the light field over a cone corresponding to object-sided numerical aperture of its lens, and a stereo camera takes two such samples. Thus any type of image acquisition system can be regarded as a (in general sparse) sample of the plenoptic function. The plenoptic function, as the name suggests contains all infor¬mation of a 3-D scene that is principally visible. Thus it results in a precise 3-D recon¬struction and the BRDF of the object surfaces is part of the plenoptic function. This also means that a general theory of all types of imaging systems (in the limit of geometric optics) is possible. In this sense novel image acquisition systems can be regarded as intelligent sampling strategies of the plenoptic function.

So far only few such possibilities have been realized including camera arrays and plenoptic cameras. Some of the research at the HCI with plenoptic cameras will be reported here. It is shown that – given the small stereo base - surprisingly accurate depth estimates gain be gained with plenoptic cameras. Our novel algorithm is based on an orientation analysis in plenoptic space and thus works also with specular sur¬faces. It is embedded in a framework with superresolution and global regularization. Future research will be directed towards active plenoptic imaging using illumination varying in space and time.



(Image from Wanner & Goldlücke, CVPR 2012)