Enhanced Resolution 3D Imaging with the Light Field Microscope

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Light field microscopy [1] is a rapid, scan-less volumetric imaging technique that requires only a standard video microscope and a microlens array. However, it suffers the drawback that spatial resolution must be sacrificed in order to record angular information in the light field, and it is this angular information that permits digital refocusing and volumetric reconstruction.

We have developed a new approach for light field reconstruction that produces a deconvolved 3-D volume with a 2-4 fold improvement in spatial resolution over ordinary light field microscopy. We exploit prior knowledge of the light field point spread function, which we model using wave optics, to perform 3-D deconvolution. This allows us to reconstruct a high resolution volume from the light field. Enhanced spatial resolution is achieved above and below the principal plane, where light field rays projecting through the sample volume criss-cross at frequent, non-uniform intervals, thereby yielding sub-voxel information. This approach is based on “super-resolution” techniques in the field of computer vision [2] (not to be mistaken with super-resolution methods in microscopy such as PALM and STORM, which seek to surpass the diffraction limit). 3D light field deconvolution greatly mitigates the problem of decreased lateral resolution, thereby addressing one of the main impediments to the widespread application of light field microscopy.

Our presentation will be illustrated by experimental (photographic) data from test targets and biological subjects. We will also provide an analysis of the maximal resolution achieved by the light field microscope and show how to adjust various optical parameters to achieve a desired lateral resolution, axial resolution, and field of view over a desired z-range in a 3-D light field reconstruction. Understanding these trade-offs will prove useful to those who hope to get the best possible performance for a given 3-D imaging scenario.

REFERENCES