

Light-field (LF) imaging has emerged as a powerful technique for capturing rich visual information by recording both spatial and angular components of light rays. Unlike conventional imaging, which integrates angular information into 2D images, LF imaging preserves this angular diversity, enabling advanced applications such as depth estimation, super-resolution, refocusing, and 3D reconstruction. However, challenges remain, including the trade-off between spatial and angular resolution, depth propagation in Epipolar Plane Images (EPIs) based LF depth estimation, limited depth range in single LF cameras, and the large and computationally intensive LF super-resolution models. Existing LF datasets fail to capture two key characteristics for disparity-based depth estimation: the inverse relationship between depth and disparity, and the dependence of disparity on focus position, resulting in minimal disparity variation.

This thesis addresses these challenges by developing novel methods to effectively exploit the spatio-angular features inherent in LF images. A comprehensive LF dataset is created, combining real-world data from the Lytro Illum LF camera and synthetic data from Blender to simulate controlled LF imaging conditions. This dataset provides ground truth disparity and depth maps, forming the foundation for evaluating LF depth estimation. For depth estimation, two approaches are proposed. The first utilizes a single LF camera and EPIs to extract depth cues from disparity. A three-stage algorithm combines region-based disparity, EPI refinement, and depth propagation to achieve high accuracy, even in occluded regions. The second approach introduces a stereo LF camera setup, extending the effective depth range. By leveraging the increased baseline between two LF cameras, disparity estimation improves for distant objects while maintaining accuracy for nearby objects through single-camera LF cues.

Additionally, a lightweight deep neural network based on a Multi-Layer Perceptron (MLP) architecture is developed for LF image super-resolution. Unlike existing methods that rely on complex 3D convolutions or transformer models, the MLP-based approach efficiently extracts angular features and helps in integration with the spatial features, delivering high-resolution reconstructions with reduced computational cost. Extensive qualitative and quantitative experiments demonstrate that the proposed methods outperform state-of-the-art techniques in depth estimation and super-resolution tasks. The contributions of this work significantly advance the practical applicability of LF imaging in areas such as autonomous navigation, virtual reality, and computational photography.