Depth Estimation from Light Fields via KLD-based Refocusing

Project Overview

This project implements a depth estimation pipeline for 4D light field images, reimplementing the method presented in [EPI-Neighborhood Distribution Based Light Field Depth Estimation](). The method leverages angular shearing and epipolar-plane image (EPI) analysis to estimate depth maps from light field datasets.

The approach focuses on computing depth via Kullback-Leibler divergence (KLD) on EPIs, allowing the identification of sharp depth peaks across different refocusing planes. Confidence maps and fusion strategies are applied to produce final, smooth depth maps.

Implementation Details

Light Field Input

- Loaded the HCI 4D light field datasets.
- Verified central sub-aperture image extraction.

Angular Shearing / Refocusing

- Implemented angular shearing based on a refocus parameter α.
- Generated refocused light field stacks corresponding to multiple α values.

EPI Extraction and KLD Computation

- Extracted horizontal (x-u) and vertical (y-v) EPIs.
- Computed symmetrized KLD across EPIs to generate horizontal and vertical depth tensors.
- Converted tensors into raw depth maps by selecting the alpha with maximum KLD per pixel.

Confidence Analysis and Depth Fusion

- Calculated confidence maps based on the sharpness of KLD peaks.
- Fused horizontal and vertical depth maps weighted by confidence.
- Applied Gaussian smoothing for final depth refinement.

Visualization

- Displayed central RGB view, raw depth maps, fused depth, and final depth.
- Grayscale visualizations highlight relative depth effectively.

Results

Key Outcomes

- Successfully reimplemented the pipeline in Python, reproducing the main steps of the reference method.
- Verified each module: input, shearing, EPI extraction, KLD computation, confidence weighting, and depth fusion.
- Generated depth maps comparable in quality to the original method.

Advantages

- **Directionally Robust**: By combining horizontal and vertical EPIs, the method handles structural variation and occlusions more effectively.
- **Confidence-Driven Fusion**: The use of confidence maps results in smoother, more reliable depth outputs and reduces noise in ambiguous regions.
- **Modular Pipeline**: Separating shearing, EPI extraction, KLD computation, and depth fusion provides clarity and makes debugging straightforward.

Disadvantages

- **Computationally Expensive**: The method scales linearly with the number of refocusing parameters (α values). A large α range is required for high accuracy, significantly increasing runtime and memory usage.
- **High Memory Consumption**: Processing full-resolution 4D light fields and storing multi-α refocused stacks requires substantial RAM or GPU memory.
- **Dense Angular Sampling**: The method depends on a full 4D light field with a large camera array (e.g., 9×9 viewpoints). Without such hardware, capturing a sufficiently dense grid of perfectly parallel images can be extremely difficult. Even small deviations in alignment or spacing can degrade EPIs and reduce accuracy.
- **Parameter Sensitivity**: Window sizes, histogram bin counts, and the α range must be chosen carefully to avoid oversmoothing or noisy outputs.