Carnegie Mellon University
Electrical & Computer Engineering

Ph.D. Thesis Defense

3D Lensless Imaging -- Theory, Hardware, and Algorithms

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ABSTRACT

Lensless cameras offer numerous opportunities to expand our imaging capabilities, from shrinking the cameras' form factor to expanding the field-of-view of microscopes. Despite their advantages, current lensless cameras have limited imaging quality that reduce their practicality. The limitations can be attributed to the complexity and conditioning of the inverse problem which resolves an image of the scene from the lensless measurements. The inverse problem posed by a scene spanning a large depth range is underdetermined and especially challenging. This thesis aims to address the role of depth in lensless imaging to effectively and efficiently photograph three-dimensional scenes. To that end, we make the following contributions.

First, we produce the first theoretical analysis on the spatial and axial resolution bounds of a mask-based lensless camera, which provides understanding for the 3D imaging resolutions of various lensless camera designs.

Second, we introduce programmable masks in lensless imagers to increase the number of measurements by capturing multiple frames while displaying different mask patterns. This upgrade in hardware allows computational focusing, so we can recover each depth with an efficient deconvolution method with few artifacts.

Finally, we present an inverse rendering approach to the challenging problem of joint reconstruction of the scene texture and shape under a physically realistic and differentiable forward model, which reduces reconstruction artifacts arising from model mismatch.

Together, those three contributions provide a fundamental advance to depth reconstruction in the context of lensless imaging.

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