

論文 / 著書情報
Article / Book Information

題目(和文)	薄型で機能的なコンピューショナルイメージングに基づくカメラシステム
Title(English)	A thin and functional camera system based on computational imaging
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学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

(博士課程)
Doctoral Program

論文要旨

THESIS SUMMARY

系・コース : Department of, Graduate major in	情報通信 情報通信	系 コース	申請学位 (専攻分野) : Academic Degree Requested	博士 Doctor of	(工学)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

This thesis presents an innovative design for a thin and functional camera system, capitalizing on the principles of computational imaging. The main objective is to create an imaging system that is both compact and cost-effective, while also offering advanced functionality. To achieve this goal, the research leverages lensless imaging technology. Additionally, the thesis delves into a learning-based refocusing reconstruction model specifically designed for the lensless camera, which is a previously unexplored aspect. Furthermore, the study explores the integration of the camera with other media functions, proposing a prototype see-through screen camera. This camera incorporates a holographic waveguide device within the media device, enhancing portability and functionality. This thesis is organized into 6 chapters.

Chapter 1 serves as an introductory section of the thesis, offering a comprehensive overview of the research background and the underlying motivation driving the study. It emphasizes the drawbacks of traditional lens-based camera systems, such as their bulkiness, high production costs, and limited functionality. Moreover, it highlights how these limitations can hinder the integration of the camera with other media functions. The chapter also provides an outline of the thesis structure and organization.

Chapter 2 provides a concise introduction to computational imaging, an innovative imaging technology that merges front-end optical encoding with back-end digital decoding to break through the limitations of the traditional optical-lens-based camera system and provide benefits in performance and camera structure. The chapter focuses on lensless imaging technology, which enables the realization of a slim camera with depth-sensitivity capabilities. Additionally, to facilitate the integration of the camera with other media functions in a portable manner, the holographic waveguide is introduced as a solution. The chapter also briefly touches upon holographic optical element-based imaging to support this integration approach.

Chapter 3 introduces the FZA lensless camera, a lensless camera that uses the Fresnel zone aperture as a coded mask. Thanks to its special design, the FZA lensless camera enables fast image reconstruction and convenient 3D processing. However, the conventional approach based on the geometrical optical model does not fully represent the real scenario due to diffraction effects, which degrades the reconstruction image quality. In this chapter, an imaging process based on the theory of wave optics is analysed, revealing the presence of zero points in the system frequency response, which negatively affects the image quality. Based on this analysis, the thesis identifies the parameters related to the location of these zeros and proposes a multi-image synthesis method for super-resolution by compensating for the zeros. Two methods are presented to achieve this super-resolution, one is to change the mask-sensor distance, but the changing distance introduces additional calibration error, so another method is proposed by changing the mask pattern, which is more robust. The chapter includes simulation and experimental results demonstrating the effectiveness of the proposed approach.

Chapter 4 proposes a learning-based refocusing reconstruction model for lensless cameras. Traditional iterative-based methods often fall short of providing a satisfactory refocusing experience due to the regularization term and time-consuming calculations. While the FZA lensless camera enables fast refocusing reconstruction, it demands high accuracy in the Point Spread Function (PSF), which can be challenging. The learning-based method, on the other hand, is purely data-driven and offers results with fewer artifacts. However, the lack of suitable datasets and a suitable structure for refocusing reconstruction have limited its development. To address these challenges, this chapter introduces an innovative approach using an external control code to select the refocusing distance with the help of a transformer-based AI model. The simulation results confirm the effectiveness of this proposed structure in achieving accurate and flexible refocusing capabilities.

Chapter 5 explores the integration of a camera into a media device with a portable size and high functionality. The traditional media system with a camera often suffers from thickness and functional limitations. For example, in an online meeting, the split design of camera and display in a conventional meeting terminal results in a loss of eye contact, as the frontal image of the user cannot be captured when looking at the screen. In this chapter, a novel approach is presented that uses the angle and wavelength selection feature of Holographic Optical Elements (HOE) to combine with the camera to create a holographic waveguide device based portable see-through display camera that can enable eye contact in the meeting. To overcome the image blur caused by the large size of the HOE for large FOV, a light ray tracing analysis considering the Bragg law is presented. A prototype camera is proposed and an optical experiment is carried out to confirm the effectiveness of the digital deblurring method. This chapter demonstrates a potential solution for creating a thin and functional camera system integrated with other media functions, enhancing the user experience and expanding the applications of the camera in portable devices.

Chapter 6 serves as a comprehensive summary of the study, providing a clear understanding of the achievements, remaining challenges and promising opportunities for future development in the context of the presented camera system.

備考 : 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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