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Flexible Modeling of Next-generation Displays using a Differentiable Toolkit

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ABSTRACT

We introduce an open-source toolkit for simulating optics and visual perception. The toolkit offers differentiable functions that ease the optimization process in design. In addition, this toolkit supports applications spanning from calculating holograms for holographic displays to foveation in computer graphics. We believe this toolkit offers a gateway to remove overheads in scientific research related to next-generation displays.

Keywords: Holography, Computer-Generated Holography, computational-optics, computational-display, perception, optics, wave-optics, machine-learning

1. INTRODUCTION

Odak is a comprehensive library for computational research in the field of optics, computer graphics, and visual perception.[1–3] It features modules for simulating optical phenomena such as ray tracing and wave optics, as well as tools for calculating perceptually-informed visual quality metrics. The library also includes functionality for importing and exporting 3-dimensional data in various formats, including point clouds and CAD files, as well as visualization tools for use during the design process. All modules within Odak are designed to be compatible with the PyTorch machine learning framework.[4] In addition, Odak is well-documented and comes equipped with a suite of test scripts to aid researchers in their work. Our library is designed to take advantage of parallel processing, and is able to run on both CPUs and NVIDIA GPUs, enabling significant speedups in computation.

2. ODAK MODULES

2.1 Computer-Generated Holography

There is a growing consensus that Computer Generated Holographic (CGH) displays can be the the next-generation display technology as they can provide all the necessary visual cues for human visual system. These displays requires a hologram calculation and interference in coherent imaging. The process of creating a CGH typically involves using computer algorithms to calculate the complex interference patterns that are required to generate the optical reconstruction in an actual holographic display. Our toolkit, Odak contains essential functions for computer-generated holography such as light transport models (refer to odak.learn.wave.classical L11-258) and optimization routines for hologram calculation (refer to odak.learn.wave.classical L261-566).

With Odak, the researchers has the flexibility to use the classical hologram generation routines (such as Gerchberg-Saxton,[5] gradient descent optimization[6] and double phase[7]) provided. Alternatively, Odak enables users to create custom hologram calculation methods by implementing custom propagation models, specific targeting schemes and varied loss models. One can use both hologram generation routines presented in the Odak or create his calculation methods using custom propagation models,[8] or different targeting schemes and loss models.[9]

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2.2 Visual Perception

Creating high-quality, artifact-free optical reconstructions in real-time using CGH is a difficult task due to the complex relationship between the desired visuals and the holograms that need to be computed.[10] Conventional display techniques, such as gaze-contingent approaches, have been shown to reduce the demands on hardware and computation.[11] The question of whether utilizing perceptual relations such gaze-contingency in CGH can be used to effectively meet the demands of the human visual system in practice is an area of ongoing research. With this idea we also provide a module for visual perception. The perception module of Odak is specifically focused on the field of visual perception, and in particular on the application of gaze-contingent perceptual loss functions. It includes an implementation of a metameric loss function,[12,13] which when utilized in optimization tasks, enforces a close visual similarity between the optimized image and the ground truth image. The loss function is derived from prior research on fast metamer generation, utilizing statistical models and computational acceleration techniques.

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