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REVIEW PAPER

Applications of artificial intelligence and digital holography in biomedical microscopy

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Abstract
Digital holography (DH) has experienced significant advancements in recent years, with improvements in both experimental and algorithmic techniques. This has resulted in an expansion of DH's applications in biomedicine, as well as other scientific and engineering fields. The introduction of machine learning (ML) and deep learning (DL) has provided a breakthrough in the recognition and prediction of patterns, especially with regards to visual imagery data. This characteristic of ML and DL makes them highly suitable for processing digital holographic data, and they have thus become widely used in digital holography. This review aims to assimilate the research where ML and DL have been employed alongside digital holography in the biomedical field for tasks such as the identification and classification of organelles, diseases, and microbes. The combination of DH and ML/DL has shown significant potential in addressing various challenges in biomedical microscopy, including the identification and classification of cellular and subcellular structures, as well as the detection of pathogenic microbes. This approach has the potential to provide new insights into the dynamics of biological systems, enabling the development of new diagnostic tools and therapies.

Keywords Digital holography · Deep learning · Machine learning · Quantitative phase imaging · Numerical reconstruction

1 Introduction

Digital Holography (DH) has made significant advances in recent years with improvement in experimental and algorithmic techniques and has found its applications in biomedicine in addition to other engineering and scientific fields. Digital Holography works by directing coherent optical signals towards an object and recording the generated interference pattern through electronic sensors. The recorded signal is used as the wavefront distribution to reconstruct the object digitally. Usually the light source is split into object beam and reference beam to capture the hologram, however, using interferometry, a single beam can also be used to capture a hologram. To capture the hologram, DH can either use the in-line technique where the object beam and reference beam follow the common optical path and perform coherent superposition on the sensor that also gives rise to twin image problem, or off-axis, where the optical paths of reference beam and object beam proceed on different optical paths which helps in elimination of twin images.

Reconstruction, and image enhancement of the digital holograph is a multistep process and involves different techniques such as depth prediction and autofocusing, numerical

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