From 2D to 3D: Advancing Diagnostic Devices with Quantitative Phase Contrast

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Background

Quantitative phase imaging (QPI) has become a significant approach that is transforming the understanding of cell physical characteristics and opening new possibilities for the development of cutting-edge diagnostic tools in oncology and hematology. Traditional diagnostic techniques
sometimes rely on expensive and invasive procedures, while QPI offers a potential non-invasive and label-free approach for imaging living cells with remarkable precision.

Research Questions

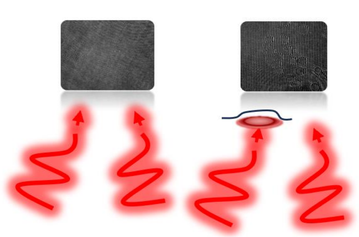
The primary goal of this study is to investigate how Quantitative Phase Imaging (QPI) may be used as a novel approach in the field of biomedical engineering for the development of next-generation diagnostic tools:

- What insights can QPI provide about cell characteristics?
- What potential improvements in diagnosis efficiency can be achieved?
- How does the choice of QPI method affect the quality of result?

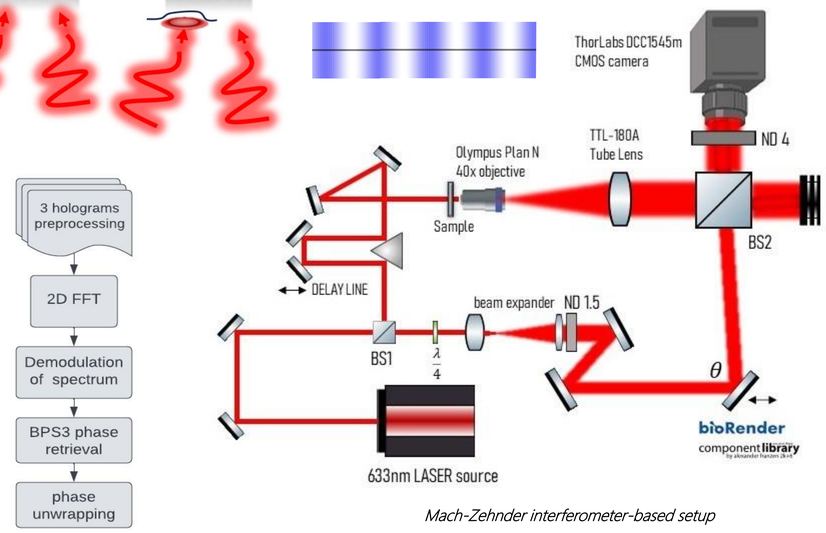
Methods

In this study, RBCs' 3D shapes have been reconstructed using Digital Holographic Microscopy (DHM). A CMOS camera and Mach-Zehnder interferometer form the base of the data collection setup. The procedure is provided in the following order:

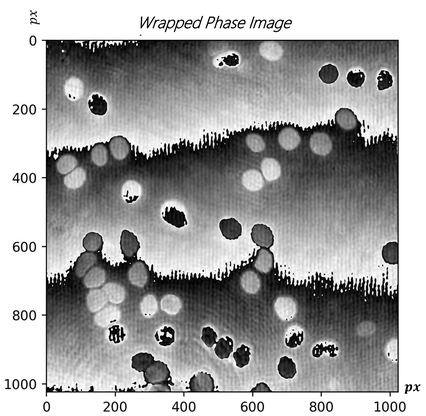
- Holograms acquisition
- Image pre-processing with Scikit Image
- Phase retrieval using the blind phase-shifting (BPS3) algorithm
- Phase unwrapping and post processing

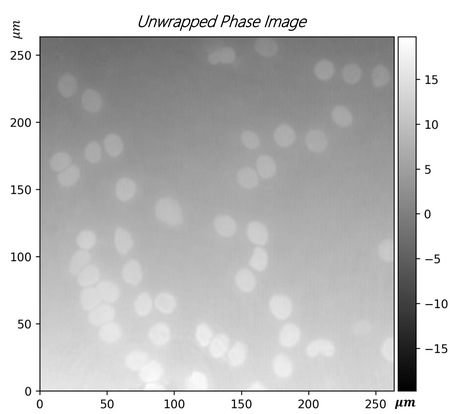


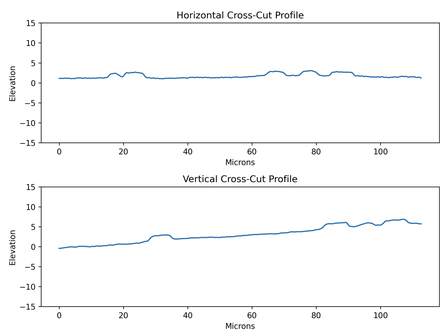
Nikon MicroscopyU phase shift simulation



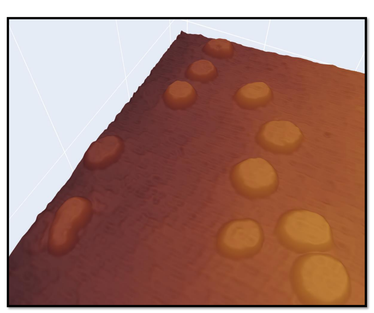
Mach-Zehnder interferometer-based setup







Cross cut profiles (xz, yz views)



Red Blood Cells 3D shape reconstruction

Outcome(s)

QPI is capable of helping detect pathomorphological changes in cells based on changes in shape, refractive index, and density. Examples of application:

- Cell classification
- Cell counting for anemia detection
- Leukemia and Hemophilia detection and tracking

Conclusion

- Improvements in QPI have made it feasible to calculate the volumetric characteristics of cells and reconstruct their precise 3D shapes for use in diagnosis.
- In comparison with traditional DHM and HPM methods, the application of phase retrieval based on ML represents a new research direction with the potential to increase accuracy and processing efficiency.
- Future directions include exploring the applications of AI in real-time data processing for abnormalities recognition.

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SciPy plotly OpenCV