**The codes for particle positioning and characterization using phase curvature curve with CNN in digital holography**

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**Description**

These codes introduce

1) The code for the training and estimation using Convolutional Neural convolutional neural network (CNN) approach.

2)The code for searching for Initial axial position guess of a spherical particle.

**Quickstart**

1. **Python Code for** for the training and estimation using Convolutional Neural convolutional neural network (CNN) approach

folder: cnn\_code\_in\_python

To start the process, simply run ' random\_ep10000\_4label\_5per\_noise.py'. ' random\_data\_5%noise\_csaps\_400mic.csv' in (1) and ' random\_label\_5%noise\_csaps\_400mic.csv' in (2) must be in this folder.

**(2)MATLAB Code** for searching for Initial axial position guess of a spherical particle.

folder: axial\_position\_matlab

To start the process, simply run ' curvature\_calculation.m'. The following codes

must be in the same folder.

1)fun\_calc\_curvature.m 2) fun\_chebychev\_240525.m 3) fun\_converge.m

4) fun\_maxz\_5\_190728\_rev.m, 5) fun\_recovery.m 6) holl\_100\_100.mat

7) holl0\_100\_100.mat 8) Miguel\_2D\_unwrapper.cpp

The particle is recorded using phase-shifting technique on the hologram, which data file is “holl\_100\_100.mat”. The data file ” holl0\_100\_100.mat” is the hologram without a particle.

The code uses Mex code( Miguel\_2D\_unwrapper.cpp), and after your code runs you might remove “mex” in fun\_calc\_curvature.m because of faster calculation.

This explanation of the processing is shown in our previous paper [1]. To solve the problem of twin images, we use a tilted reference wave for a single-shot phase-shifting method. This method uses a real-time phase shift between three adjacent pixels on the camera, adjusting the oblique reference wave [2]. To extract this phase curvature from a particle, the reconstructed image is calculated using the phase-shifting algorithm and the angular spectrum method [2], and we extracted the centroid (xp,yp) of the transversal intensity of the reconstructed particle. Next, we find the point of minimal intensity of the centroid along the z-direction and calculated the zero-crossing point of the curvature pattern around the point of minimal intensity. Consequently, we chose this value as a zp guess (Fig. 1) and calculated the curvatures using phase φ(xp,yp,zp) at several designated points, except zp.

**References**



Fig.1 The pipeline of curvature calculation for experimental data. A reconstructed wave is obtained from the angular spectrum method using a hologram.

1. S. Hasegawa and T. Miaki, "Machine learning techniques for positioning and characterization of particles in digital holography using the whole phase curvature," Opt. Continuum **1**, 2561-2576 (2022)]
2. S. Hasegawa and T. Miaki, "Whole phase curvature-based particle positioning and size determination by digital holography," Appl. Opt. **59**, 7201-7210 (2020)