An Accessible Python Library for Magnetic Tweezer Bead Tracking

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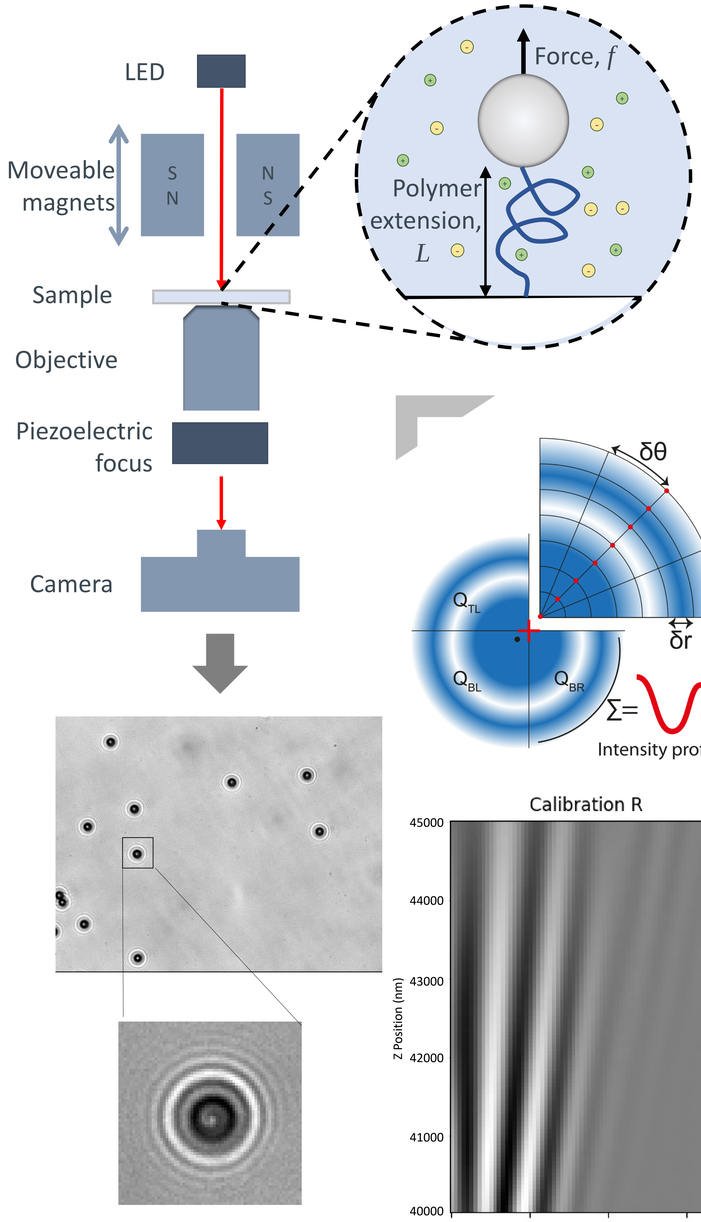
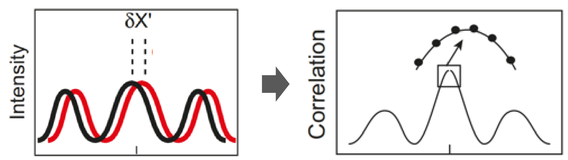
Problem & Project Goal

Single-molecule manipulation experiments are powerful tools for studying biomolecules, but they are not widely accessible, as they rely on expensive turn-key instruments or complex custom-built setups. We introduce **an accessible open-source software distribution for the magnetic tweezer**, one particularly simple instrument. The program can track 20 beads simultaneously at 60Hz with less than 10 nm error in 3-D, comparing favorably to other implementations.[1]

Magnetic Tweezer



Steps to Track Beads in 3-D



1. FFT for XY positions

- Sample and average to get a slice of pixels near the center
- Cross-correlation with Fourier Transform finds the symmetry center of pixels
- Iterate to reduce fitting error

2. Bilinear Interpolation[2]

- Re-sample the bead image
- Average radial intensity profile
- Can be GPU accelerated

3. Z from profile

- Calibrate by moving Piezo
- Filter profile in Fourier space
- Generate a look-up table
- Fit weighted difference in phase

Scan the QR code to explore our code

Taichi Lang

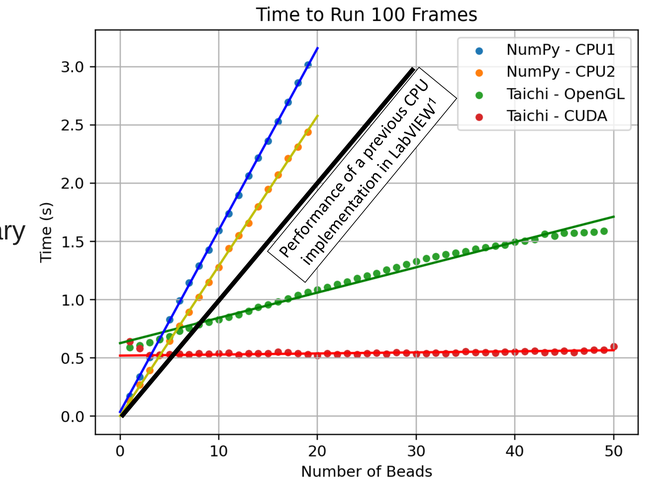
Code Implementation

- Straight-forward Python interface
- Open source on Github
- General hardware support with 2 versions:
  - CPU: with library NumPy
  - GPU: acceleration with library Taichi, **automatically** support CUDA, OpenGL, etc.

Efficiency

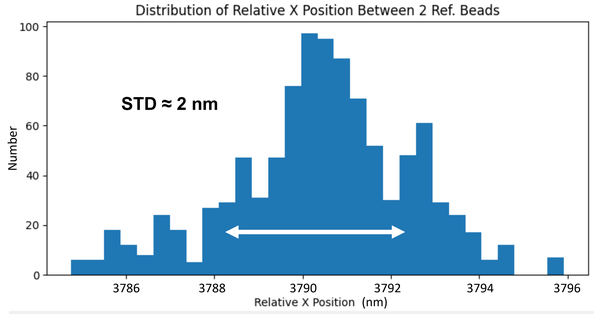
- Outstanding performance for a Python library
- Comparable to previous implementations

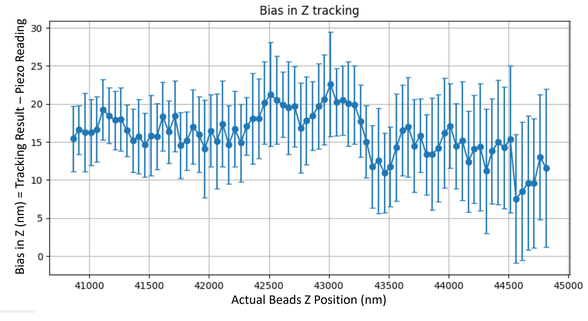
Tested with simulated images with 1000 x 1000 pixels
CPU1: Intel Core i7-8650U CPU @ 1.90GHz
CPU2: Intel Core i7-2600K CPU @ 3.40GHz
OpenGL: with NVIDIA Quadro 4000
CUDA: with NVIDIA GeForce GTX 1050



Precision

Sufficient precision for biomolecular experiments





Left: Tested with experimental images of reference beads. Tracking 2 reference beads for 1000 frames.
Right: Tracking one reference bead with different focal distance Z after calibration with Piezoelectric

Conclusion

In this project we have developed an accessible Python library for bead tracking in magnetic tweezer experiments. It has considerable precision and efficiency, and it is adaptable to various platforms. In the future we will test the program in real biomolecular experiments.

Acknowledgment

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Reference

1. Ribeck, Saleh. (2008). *Review of Scientific Instruments, 79*(9), 094301.
2. van Loenhout, et al. (2012). *Biophysical Journal, 102*(10), 2362-2371.