OpenLPTGUI: A user-friendly GUI for 3D Lagrangian particle tracking

31 August 2024

Summary

In experimental fluid dynamics, the velocity of the flow can be measured by capturing the motion of numerous small tracer particles that accurately follow the flow (Papantoniou and Dracos 1989; Nishino, Kasagi, and Hirata 1989). Lagrangian particle tracking is one of the most popular ways to quantify the flow, which can obtain longer particle trajectories than the other methods (Schanz, Gesemann, and Schröder 2016; Tan et al. 2020; Shnapp 2022; Barta et al. 2024). Such advantage makes this method widely applied for studying particle dispersion, mixing, and other transport-related quantities (Tan and Ni 2022; Godbersen et al. 2021; Qi et al. 2022; Schröder and Schanz 2023; Masuk et al. 2021; Tan, Zhong, and Ni 2023). The idea of Lagrangian tracking is to first reconstruct 3D positions of particles based on images from each syncronized camera; and then link the positions at different frames to generate particle trajectories. By using iterative particle reconstruction algorithm (Wieneke 2012), the number and accuracy of reconstructed 3D particles can be highly increased. With shake-the-box algorithm (Schanz, Gesemann, and Schröder 2016), the length of particle trajectories can be extended faciliating the study of long-time dispersion (Tan and Ni 2022). The optimized code, called `OpenLPT`, has been well-established and uploaded to github (Tan et al. 2020). However, this code was written in C++ without user-friendly API or GUI, making it hard for people in the community to compile and use. In this work, we present an updated version of this code with user-friendly GUI and python-based API, dedicated to making OpenLPT more accessible to the scientific community.

Statement of need

`pyOpenLPT` is an OpenLPT-affiliated Python package for three dimensional Lagrangian particle tracking. The source code, written in C++, is designed to handle dense particle tracking ($\sim O(5 \times 10^4)$). Compared with the old version (Tan et al. 2020), several new features have been added: (1) the polynomial camera model is added to the new code; (2) have more capability of calibraiton; and (3) flexibility with number of cameras and reduced cameras.

The new code has also been restructured and organized to be more modular and extendable, making it easier to incorporate new features, such as complex object identification, tracking, and simultaneous tracking of multiple types of objects. The Python package, `pyOpenLPT`, wraps the low-level code written in C++, keeping its high efficiency without losing flexibility or ease-of-use in the user-interface. The installation for this package can be finished in several lines and supports for both Windows and Linux systems.

The GUI for `pyOpenLPT`, called `OpenLPTGUI`, is designed to offer a user-friendly graphical interface, making it accessible for users of all backgrounds to apply Lagrangian particle tracking for flow measurement. The interface features a clear, step-by-step workflow, and comprehensive documentation is included in the code folder. The workflow includes: calibration points extraction, camera calibration, image pre-processing, tracking, and camera parameter optimization (see Figure 1). A sample results with 50% of tracks is shown in Figure 2.

The code family (`OpenLPT`, `pyOpenLPT` and `OpenLPTGUI`) has already been used in a number of scientific publications (Salibindla et al. 2020; Qi, Masuk, and Ni 2020; Masuk, Salibindla, and Ni 2021a, 2021b; Salibindla, Masuk, and Ni 2021; Masuk et al. 2021; Qi et al. 2022; Tan and Ni 2022; Tan et al. 2023). With the new version of the code family, the advanced software can be more easily adopted by the experimental community, enabling more researchers to obtain high-quality 3D flow measurements and make exciting new discoveries.

Current capabilities

`pyOpenLPT`, currently in version 0.1.0, includes all the essential code required to extract 3D particle trajectories from image data. It currently does not support 2D tracking. But it could be added in the future. It currenly does not combine the code for tracking spherical objects (Tan, Zhong, and Ni 2023), but it will be added in the next few versions.

Acknowledgements

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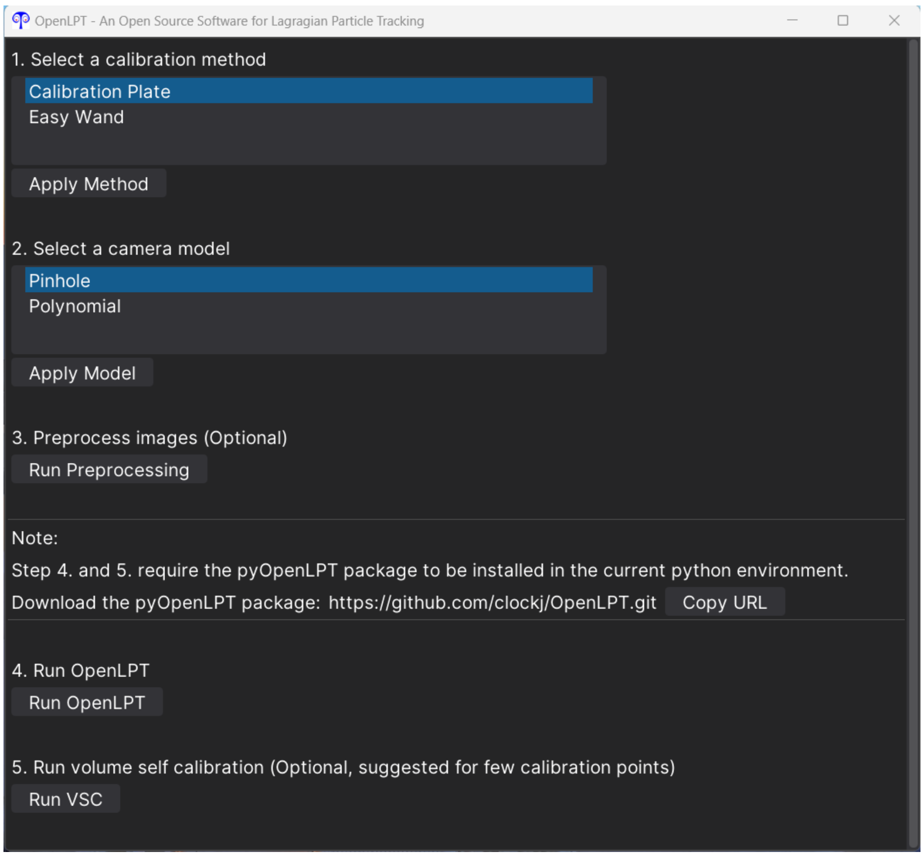

Figure 1: OpenLPTGUI main page.

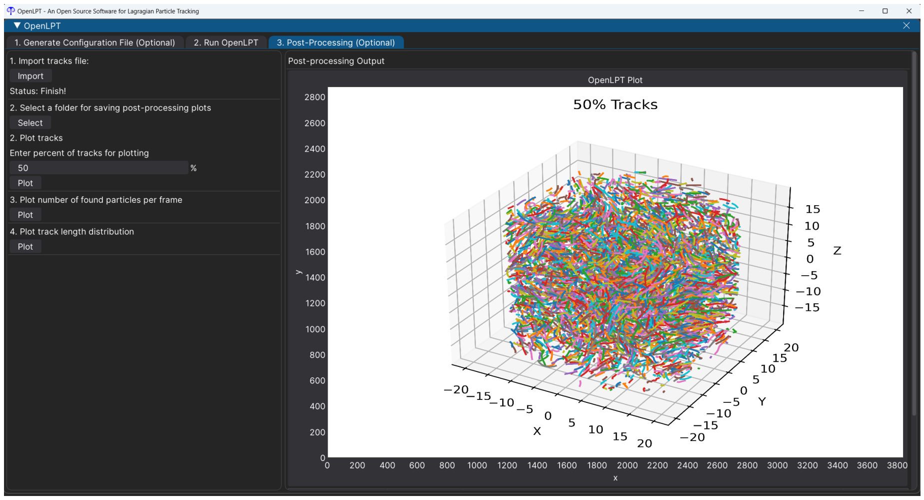

Figure 2: OpenLPTGUI post-processing for plotting 50% of tracks.

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