High Speed Particle Image Velocimetry

Overview

The Department of Energy's National Energy Technology Laboratory is seeking licensing partners interested in implementing U.S. Non-provisional Patent Application 12/765,317 entitled "Method of Particle Trajectory Recognition in Particle Flows of High Particle Concentration Using a Candidate Trajectory Tree Process with Variable Search Areas."

This patent application discloses a novel method to simultaneously track the motion of high numbers of object images under extreme, high concentration conditions. Although the software is designed to simultaneously track large numbers of particle images in flow fields, it can track any type of object whose locations are available at consecutive time increments (e.g., consecutive video frames).

Particle flow fields of high particle concentration are found in many commercial applications, including chemical processing, energy conversion, pharmaceutical processing, foods processing, and biomedical applications. This technology will allow, for the first time, the measurement of particle motion within high particle concentration fields.

Using a novel "Candidate Trajectory Tree Process," this technology overcomes well-known problems, such as correspondence ambiguity, crossing trajectories, and loss of images, that are common to video sequences of large numbers of objects at high object concentrations. For each object image, a tree of candidate trajectories is formed using extrapolative search techniques. Search areas of novel size and shape are formed based on Newtonian properties of motion such as velocity and acceleration. The search areas range from minimum sizes, which first detect slower moving objects, to a maximum size that detects the fastest objects.

A fast, accurate computational framework has also been developed.

The software has proven to be computationally quick and precise on a wide range of particle flow applications. High-speed videos with up to 40 million particle images over 200,000 video frames have been analyzed in minutes or hours on personal computers, and up to 1,000 particle images have been simultaneously tracked through hundreds of video frames. Additionally, the software has accurately tracked high concentrations of particles undergoing purely random motion, similar to Brownian motion.

Significance

This method of simultaneously tracking high numbers of objects at high object concentrations offers the following benefits. The method—

- is computationally fast because it overcomes the computational explosion caused by the well-known "correspondence ambiguity" problem inherent in prior methods of object tracking
- overcomes the problem of trajectory crossing and image loss common to tracking high numbers of objects
- tracks objects or particles in highly concentrated, dense flow fields, which was not possible before;
- can be applied to single phase flows to measure fluid motion by seeding fluids or gases with tracer particles
- can be applied to track large numbers of any type of object, provided that object locations are available at consecutive time increments
- can be used to extend the conventional double frame (or double image) PIV technique to track Lagrangian fluid motion over long periods (e.g., thousands of high speed video frames)
- has applications to a wide range of industrial, environmental, and medical challenges, wherever object tracking is essential

This software technology reads raw video sequences and automatically produces data for object motion, including object velocities, trajectories, and concentrations. The data is in the form of two-dimensional maps of velocity and concentration for each camera frame. The software also provides trajectories of objects through hundreds or thousands of frames.

Thus far, the technology has been primarily used to measure and analyze single-phase fluid motion (using tracer particle) and multiphase particle motion with high particle concentrations. The technology has successfully mapped particle motion at very high particle concentrations in circulating fluidized beds at several laboratories. In another application, the technology mapped the turbulent motion of blood analog fluids around a 4mm-diameter turbine spinning at 20,000 rpm in a medical device. Fluid flow undergoing cavitation has been mapped in a water tunnel. This technology was also used by the Unified Command Flow Rate Technical Group to estimate the amount of oil leaking from the Deepwater Horizon Macando Well in the Gulf of Mexico. The technology allowed researchers to estimate oil flow rate by tracking hydrate particles and vortical flow structures in the oil leak jets.

This technology can also be used to extend the well-known, double frame (or double image) particle image velocimetry (PIV) technology to analyze fluid motion through thousands of video frames (sometimes called time resolved PIV).

This technology has been used with small diameter (less than 0.5” diameter) borescopes to probe into opaque, high-concentration flow fields.

Contact

Jessica Sosenko
412-386-7417
jessica.sosenko@netl.doe.gov

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