Particle image velocimetry used to see physiology

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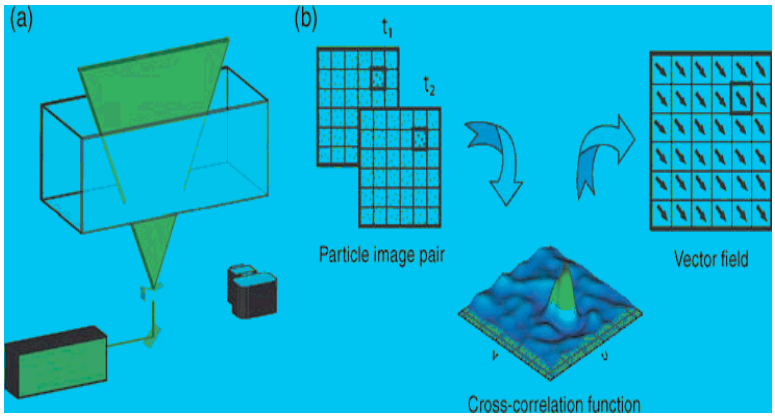
Despite the array of sophisticated imaging techniques available for biological applications, none of the standard biomedical techniques adequately provides the capability to measure motion and flow. This technique of velocimetry is a well-established tool in engineering research and industry. Particle image velocimetry is continuing to develop and has an increasing number of variants.

Three case studies are presented: **(i)** the use of microparticle image velocimetry to study flow generated by high-frequency oscillatory ventilation in a human airway model; **(ii)** the use of stereoparticle image velocimetry to study stirred cell and tissue culture devices; and **(iii)** a three-dimensional X-ray particle image velocimetry technique used to measure flow in an *in vitro* vascular flow model.

As is well known, between 60 and 70% of the human body is comprised of fluids. A range of important fluid flows occur, such as blood flow, airflow in the respiratory tract, lymphatic flow and lubrication of synovial joints. Many of these flows are highly complex and have not been well quantified, thus limiting our understanding of thephysiological systems in which they occur.

A wide range of imaging techniques is available for biological applications, including microscopy (bright-field, fluorescent, phase contrast and confocal), magnetic resonance imaging (MRI), radionuclide imaging, X-ray angiography, X-ray computed tomography (CT), X-ray videodensitometry, video cross-correlation tracking and ultrasonography. These techniques have extremely poor spatial and temporal resolution and can only characterize flows as a single parameter rather than as a velocity field that may vary in space and time.

As the name suggests, PIV is an image-based technique.Typically, laser light is used to illuminate the region of interest, which includes fluid seeded with reflective tracer particles. These particles are usually close to neutrally buoyant in order to adequately describe the flow. Pairs of images separated by a known time interval are typically captured using a charge-coupled device (CCD) camera, which is synchronized with the laser. In its most basic form, PIV analysis involves subdividing each image into a grid-like set of sampling windows and performing a cross-correlation analysis between corresponding sampling windows in each frame. The instantaneous velocity at each grid location is then simply the ratio of the measured displacement and the time separation between images.



The optical nature of PIV is the source of its greatest strengths and limitations. The technique allows simultaneous measurements over the area of a field of view, but requires visibility of that area to perform those measurements.

However, many physiologically important models that allow optical access have been developed. These include models such as embryos and small animals (e.g. zebrafish). Examples of PIV application to biological research include the use of PIV to measure blood flow profiles in surgically exposed mesenteric vessels of rats, and the measurement of blood flow velocity within an embryonic avian heart. The aim of the present paper is to introduce biologists to further possibilities of PIV application.

Sources:

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