Towards a Schlieren Camera

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We describe progress towards the construction of a schlieren camera that can perform real-time schlieren imaging at 30 frames per second. Schlieren imaging is a technique used to visualize changes in the refractive index of a transparent solid or fluid medium. Until recently, the object or flow to be imaged had to be placed within a schlieren imaging system, which is often a large and cumbersome optical assembly [1]. With the exception of the so-called focusing schlieren system [2], the size of the area that could be imaged was limited by the size of the primary lenses or mirrors making up the imaging system. Thus, imaging large fields of view (≥ 50 cm) was almost impossible due to the prohibitive cost of the optical components needed to build the system.

However, the easy availability of cheap and powerful computers and digital cameras has led to a new form of schlieren imaging called Background Oriented Schlieren (BOS) [3], or Synthetic Schlieren [4]. In the BOS technique, the flow to be visualized is interposed between a camera and a background screen or grid. The flow causes local changes in the refractive index of the intervening medium, which in turn results in a distortion of the image of the background screen. By comparing the apparent shift of features between the distorted and undistorted images, the changes in the local refractive index or the density of the medium can be extracted. The apparent shift is usually found using Fourier-based image cross-correlation techniques which are computationally very intensive. We have developed a novel background pattern that does not require correlation techniques to find the image shift. The technique is accurate enough to enable us to measure displacements as small as 20 micrometers, reliably, at a camera-to-screen distance of 3 meters.

The reduction in computational effort obtained by using the modified background screen motivated us to consider whether we could take advantage of multi-core GPU chips, which are now part of almost all graphic cards, to perform real-time synthetic schlieren imaging. One drawback of current BOS and synthetic schlieren techniques is that the images cannot be processed and viewed in real-time due to the computational cost of the cross-correlation techniques. We have used the GPU board present on a MacBook Pro laptop along with its built-in webcam to obtain real-time schlieren imaging at 30 fps using a simple subtraction algorithm.Work is in progress to implement a more sophisticated algorithm. We will also describe biological applications of our work which are being used to study odor-following behavior in fruit fly larvae.

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