Problems with using optical flow algorithms for volumetric sources

Utsunomiya Univ., Nathan Hagen

E-mail: hagen@cc.utsunomiya-u.ac.jp

Optical flow algorithms were originally developed for estimating the motion of opaque objects. In the case of semi-transparent fluids, the object is a volumetric distribution that exhibits motion in three dimensions. In principle, adapting optical flow algorithms to 3D flow seems simple: we still have a 2D image to work with, representing a projection through a 3D volumetric object. And now we need only consider the velocity estimate as being an average through the object along the line of sight, instead of the velocity at a single point. Unfortunately, however, this simple step creates flaws in the algorithm that are easily overlooked.

The largest error occurs due to optical flow algorithms' use of the spatio-temporal gradient to estimate. If the volumetric flow is nonuniform, such that some layers along the line of sight flow with different velocities and/or different directions, taking the gradient of the projected image removes information about the nonuniformity. As the thought experiment below illustrates, this means that the estimated velocity of the fluid along the line of sight is weighted not by the concentration, which would allow accurate flux estimation, but by the *gradient* of the concentration.

These problems imply that a 3D flow simulation, and not just the 2D projection of flow, is necessary to properly estimate the volumetric flux.

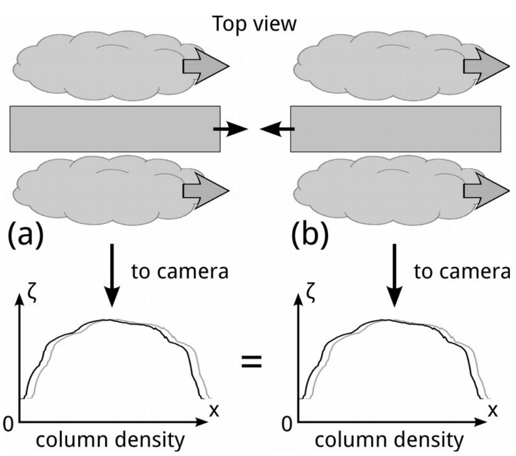

Figure 1. A thought experiment of measuring the column density of a scene consisting of three fluid distributions within a scene: two gas clouds moving to the right and a spatially uniform layer moving to the (a) right or (b) left. Each of the three objects are of homogeneous density, but only the central rectangular layer has zero spatial gradient. The plots shown underneath give the resulting (identical) gas column densities imaged by the camera, for the current frame (in black) and the following frame (in gray).

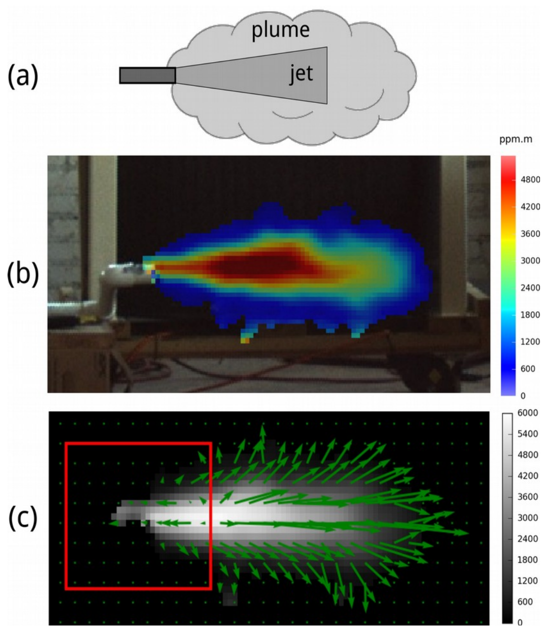

Figure 2. A jet-and-plume experiment for quantifying flux, showing a methane gas release from a pipe with an inner diameter of 5 cm. (a) A schematic showing the components of the fluid flow for simulation, (b) a visualization of the experimentally measured gas column density overlaid on a visible image, and (c) the estimated gas velocity vectors.