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# Optical flow of non-integer order in particle image velocimetry techniques

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**Abstract**

High resolution particle image velocimetry (PIV) is an experimental method that has recently improved the measurement of particles velocity in flows after the advent of high resolution cameras. Nonetheless, the improvement in spatial resolution, the accuracy and performance of the velocity measurement techniques developed so far, are prone to improvements by new mathematical tools. As the current techniques are based on conventional calculus, the non-integer order or fractional calculus is becoming a more attractive technique since it predicts better than conventional calculus several phenomena in areas like complex fluids, mechanics and electrodynamics, among others. In this article, three main optical flow algorithms used in PIV are expressed in terms of fractional calculus for improvement of their performance in velocity measurements. The experimental results show the accuracy improvement obtained from the use of fractional calculus for velocity measurements.

*Keywords:* Optical flow, Fractional calculus, Particle image velocimetry



## 1. Introduction

The quantitative measurement of flow velocity is essential to comprehend the physics behind a complex flow during the research of fluid dynamics as well as aerodynamics [1, 2]. The quantitative measurement of flow velocity is not an easy task, there are several methods that can be used for the measurement [2, 3], most of them are based on laser diagnostics, image processing, and high-speed data acquisition [1, 4]. Particle image velocimetry methods of flow visualization and velocity measurement are frequently used in research of fluid dynamics and aerodynamics [1, 5]. The main goal of the methods is to give accurate velocity measurement and related properties in fluids. The fluid under study for PIV contains tracer particles small enough so that their presence does not change the motion properties of the fluid. The fluid with embedded particles is illuminated with enough light power to highlight the presence of the particles in the fluid, and the motion of the seeded particles is used to calculate speed and direction of the flow under study. A typical PIV optical setup uses a high speed camera, and the illumination is usually provided by a laser beam [2, 3] that is converted into an illuminating sheet using cylindrical lenses, external time synchrony is usually provided using a trigger for simultaneous control of camera acquisition and emission of laser pulses. As a final process, the PIV images obtained by the camera are processed by software algorithms of optical flow calculation that are used to extract the particles velocities [2, 3]. Particle image velocimetry methods are non-invasive, and provide information of the fluid velocity in two and three dimensions mainly using correlation algorithms with accuracy that is still prone to improvement. The most common method uses two adjacent tracer particle images, and subdivides the images into smaller windows to compute the correlation among pairs of adjacent windows [3]. As a consequence, the PIV's measurements correspond to an average value that depends on each windows pair, so the information processed also depends on the windows size and therefore the PIV resolution is always constrained by this size [1, 4]. Improving the spatial resolution of measurement is key to understand the dynamic information of a turbulent and complex unsteady flow. Alternative algorithms have been proposed to study the velocity in a complex flow [6, 7, 8, 9]. In [5] the authors proposed the Horn-Schunck algorithm.

The Horn-Schunck originally was implemented in stereographic applications but its performance in comparison to other optical flow algorithms of stereographic applications is low [10]. In this context, the optical flow algorithms like the Horn-Schunck and others like