Accuracy assessment of image interpolation schemes for PIV from real images of particle

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Nowadays, Particle Image Velocimetry (PIV) is a well-developed measurement technique, which is widely used for fundamental research and industrial applications. In the past five years, in order to improve the accuracy and reliability of velocity measurements, numerous advanced PIV algorithms have been proposed. Each one integrates different concepts, but in general all of them extensively use image interpolation technique. It has been shown that this step can have significant consequences on the final accuracy of the velocity measurement. A second important aspect of an interpolation scheme step is its performance in terms of computation load. The choice of an adapted image interpolation scheme is then always a compromise based on accuracy and efficiency, but unfortunately it cannot be considered universal for all the situations. Indeed, this choice is also strongly dependent on image characteristics (noise, particle image size....). For instance, if we look at the negative effect as “peak-locking” observed on the velocity measurements, its source and its reduction depend on multi-parameters such as image interpolation, PIV algorithm, correlation peak interpolation, image acquisition (CCD pitch, lens aperture, optical magnification...). So, it is obvious that the choice of an interpolation scheme becomes tricky because all these parameters have to be taken into account.

Up to now, the performance assessments of interpolation schemes have been mainly conducted using synthetic images. These approaches are useful to produce an ideal situation of acquisition and to evaluate PIV algorithms (including interpolation) and its response to a given parameter (particle image size, optical magnification...). Nevertheless, whatever the quality of the synthetic image generator and the sophistication of their physical models, the simulation of the entirety acquisition step remains a challenge (ex: speckle noise, image distortion...) and then the impacts of conclusion have always to be extended with care to real conditions. In the present paper, an original experimental approach to assess the performance of different image interpolation schemes from real images of particle is proposed. The experience is based on a laminar jet of air seeded with oil droplets. The jet, with a flat and uniform velocity profile, is used to produce images of particle with known particle displacement in a range of 0 to 3.2 pixels by step of 0.1 pixel. Six different interpolation schemes have been compared by using an advanced PIV algorithm based on continuous window shift technique CWS (Lecordier and Trinité, 2003). In order to evaluate the potential of the interpolation schemes in large range of experimental conditions, particle images have been recorded for two different optical magnifications (0.044 and 0.1) and different lens apertures (f/d: 1.2 to 16).

The PIV apparatus consists of a double cavity Nd:YAG laser delivering pulses of 120mJ @532nm associated with an interline CCD camera (Lavision – flowmaster3) with a Nikkor lens (50 mm – f/d=1.2). In order to compare the interpolation schemes, images of the laminar jet at the exit of the nozzle have been recorded. Thank to the very stable flow conditions of the jet, the particle displacement on the images is uniformed. In order to modify particle displacement on the images rather than changing the flow rate which could introduce large uncertainties, the time separation between images of particles has been adjusted with constant flow conditions. In addition, for reducing acquisition time and then ensure to preserve constant flow conditions during the whole acquisition step, an automatic acquisition sequence changing the time interval between images has been developed.

In Figure 1, the RMS of the measured displacement is presented for two lens apertures. From these results, the peak-locking is clearly observed for particle displacement with a fractional part close to 0.5 pixel. As expected and shown from analyses of synthetic images, this bias is higher for large lens apertures than small one. Two interpolation schemes (bilinear and sinc3x3) generate quite large RMS whatever the lens aperture. Nevertheless, the differences between the other interpolation schemes are not as significant as those observed from synthetic image and they lead to the same accuracy. These results show the difficulties to optimise the image interpolation scheme in real conditions. This paper will present the different results of the accuracy assessment from real images of the main image interpolation schemes used for PIV.

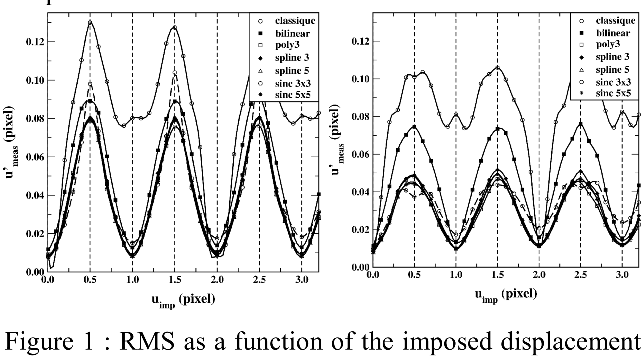

Figure 1 : RMS as a function of the imposed displacement for the conventional and CWS PIV approaches for two lens apertures (f/d = 1.2 – left, f/d = 8 – right) and 6 image interpolation schemes.

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