Development of an optimized 2D particle tracking velocimetry (PTV) code

Mathieu ROUVINEZ

1. Introduction and concept
The purpose of the project was to write a computer program. Given a video capture of particles seeded into a fluid, this computer program had to be able to perform particle detection, particle image velocimetry (PIV) and ultimately particle tracking velocimetry (PTV). Written in the C++ programming language, the code behind the program was optimized for speed of execution by the use of efficient algorithms and parallelization of the most computationally intensive tasks.

2. User interface
The graphical user interface was implemented with Nokia Qt and allows the user to visualize video files, to choose the settings for particles identification, and to see the displacement vectors of particles computed by the PIV and the PTV methods.

3. Performance programming
Single instruction - multiple data (SIMD) instructions and multithreading were used in order to take advantage of the computing capabilities of modern microprocessors. Performance oriented techniques like loops unrolling, branch-less code paths, and bit-level manipulations helped to lower the amount of instruction cycles required for the completion of a given computation.

4. Methods and algorithms used
Particle detection is based on the least squares fitting of a circular 2D Gaussian function. The position of each particle can thus be determined to a sub-pixel level of precision.

Particle image velocimetry (PIV) relies on the identification of the peak of displacement in local maps generated by normalized cross-correlation of two consecutive frames.

Particle tracking velocimetry (PTV) uses both the results of particle detection and particle image velocimetry: the PIV displacement map is used as a first guess, then exact displacement vectors are given by the difference of real positions of particles found by least squares fitting.

5. Results
The program generates a view of the pathlines of particles. In the following example, the fluid seeded with particles flows through the inverted T-junction from the inlet on the top to the outlet on the right:

In the next illustration, the map of displacement vectors generated by the PIV method executed on two consecutive frames shows a qualitatively correct description of the general motion of particles:

The following magnified detail taken from another video sample shows two consecutive frames where particles move in the top-right direction. The displacement vectors are identified by the PTV method and these vectors link the positions of particles in their motion from one frame to the next:

Compared to particle image velocimetry (PIV), particle tracking velocimetry (PTV) leads to a better level of extraction of informations from the images because the displacement of each particle is used. The computed displacements obtained from the PTV method are also more accurate since they rely on the particle detection process which is sub-pixel level accurate.