

# SINGLE-VIEW SUPER-RESOLUTION WHOLE-FIELD VELOCITY AND SCALAR MAPPING TECHNIQUE

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**Summary** Innovative technique consists of two major components. First, a new algorithm, which relies on the accurate recovery of location, diameter and intensity provided by each individual tracer particle image spot has been proposed and experimentally demonstrated. Second, a novel single-view particle tracking velocimetry technique enhanced by pairs matching based on tracer particle random size variety has been established and experimentally demonstrated. Feasibility, limitations and most attractive embodiments of this technique are evaluated. Employing mask-free defocusing for pure 3-D volumetric visualization, it is an attractive alternative not only to well-established stereoscopy, recently developed defocusing by aperture masking digital particle image velocimetry, but also to holography, tomography, magnetic resonance imaging, etc., for a number of particular applications ranging from micro fluids to large scale industrial facilities. Applying two-colour pyrometry to each tracer for whole-field velocimetry/thermometry, it is a competitive alternative for more sophisticated technologies (e.g. filtered Rayleigh scattering, Coherent anti-Stokes Raman Scattering, etc.).

## INTRODUCTION

Optical non-intrusive sensing to measure both velocity and scalar (e.g. temperature) distribution in a variety of different flows is one of the promising diagnostics methods allowing to extract spatial distribution and temporal behavior of both simultaneously.

Particle Tracking Velocimetry (PTV) and Particle Image Velocimetry (PIV) are well-established extremes of the general class of Particle Imaging Techniques (PIT) for visualization over extended regions of a flow with high spatial and temporal resolution. Both extremes of PIT, PTV and PIV, originally have been established for velocity field visualization only, for a planar two-dimensional (2-D) flow domain.

In the meantime flow fields of interest in classical and applied fluid mechanics are essentially three-dimensional (3-D) and inseparable from scalar parameter (e.g. temperature) effects in the majority of cases. A number of techniques have been developed to expand PIT to third dimension (stereoscopy, holography, aperture masking defocusing, etc.), as far as to simultaneous scalar map recovery, in the case when scalar is the temperature, thermochromic liquid crystal (TLC) digital Particle image velocimetry [1], filtered Rayleigh scattering, (FRS), Coherent anti-Stokes Raman Scattering (CARS) should be mentioned at first. One of the major drawbacks in the way of attempted extensions of PIT to third (3-D) and fourth (scalar) dimensions is usually different physical nature of characteristics used to do so.

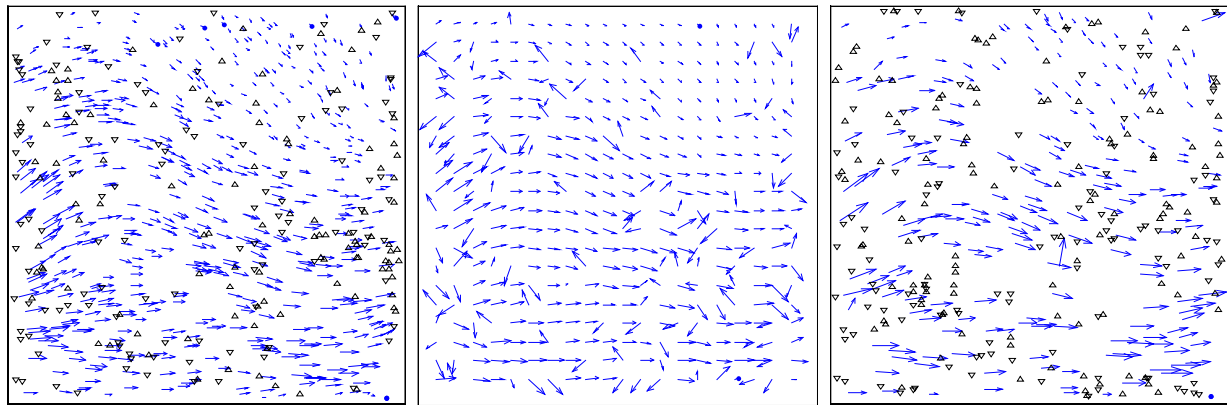
Ideal combination of 3-D velocity and scalar mapping should be able to provide approximately equal both spatial and temporal resolution as high as possible using same physical principles to accurately measure both, velocity and a scalar. Here we propose a new algorithm to accurately recover location, diameter and intensity provided by each individual tracer particle image spot and a novel particle tracking technique enhanced by pairs matching based on tracer particle random size variety which are, coupled together, an attempt to expand PIT from conventional two to four dimensions, regardless of certain physical phenomenon involving to provide simultaneous 3-D velocity and a scalar mapping. The feasibility of this technique is validated by error and limitations analysis. The performances are evaluated by demonstrational experiments. Preferred embodiments are discussed.

## ASSUMPTIONS AND PRINCIPLE

In present work inherent or laser induced irradiation of individual tracer particles or distinguishable groups of molecules (injected into hot flow in the form of liquid evaporating droplets) is examined as information source of both scalar (e.g. temperature) and velocity fields. It is assumed and analysed a detectable contribution of 4-D parameters (3-D position and a scalar parameter) to 4 on-sensor parameters (location, diameter and intensity) of each distinguishable tracer image spot on sequent captured image patterns. Appropriate algorithm has been established and verified. Another component of this technique implies Enhanced Particle Tracking Velocimetry (EPTV) by pairs matching on sequent images based on tracer particle random size variety.

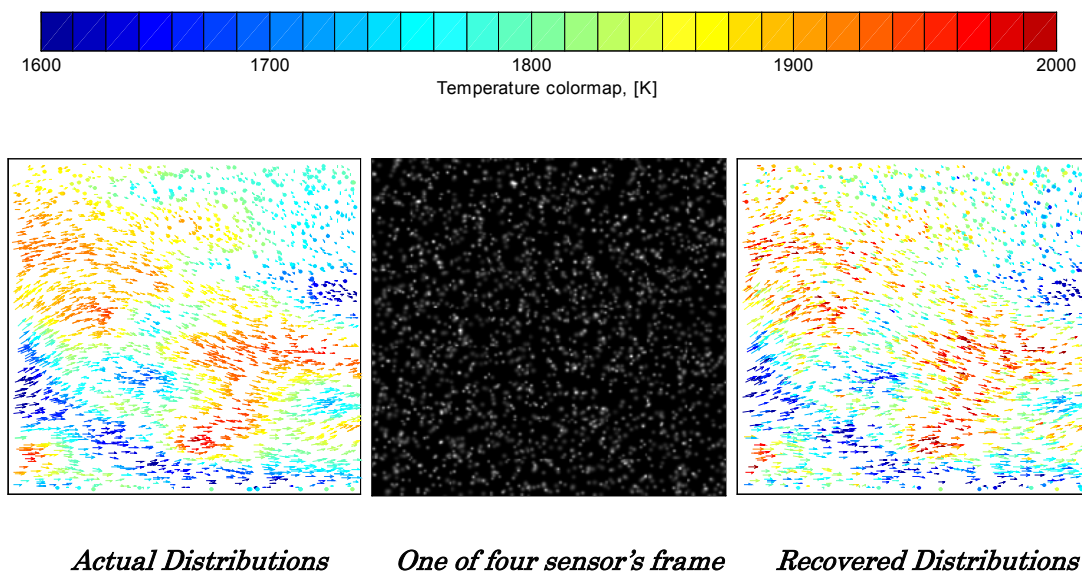
## VALIDATION AND DEMONSTRATION

Feasibility, limitations and most attractive embodiments of the technique as applying primarily to 3-D velocity and temperature flows visualization using commercially available visible and near-infrared CCD sensors are analyzed. Error analysis of the measurement system has been carried out using numerically simulated images and modelling experiments for preferred technique embodiments. To illustrate some of features, a comparative example of Enhanced PTV technique application for standard computer simulated sequent images provided by VSJ (Japan) is given on the Fig.1. A technique application for simulated velocity and temperature fields is depicted on the Fig.2.



**Actual Distributions**                      **Cross-Correlation**                      **Enhanced PTV Model**  
 Velocity field from Custom Made Images provided by PIV Standard Project, VSJ Japan, <http://www.vsj.or.jp>, (Serial Number CM2-2558). **Left:** actual velocity and non-paired particles field; **Centre:** cross-correlation, 32x32 window size, 0.5 overlapping, without any filtering; **Right:** EPTV Model without any filtering. Triangles on these pictures note non-paired particles: triangle-downward (v) – particle, leaving light sheet, triangle-upward (^) – particle, entering light sheet.

**Fig. 1. A Comparative Example of Enhanced PTV technique application.**



**Fig. 2. Technique application for simulated velocity and temperature fields of 2489 vectors captured by noisy 8-bit 256x256 sensors, 2245 are recovered with high accuracy.**

## CONCLUSIONS

Proposed technique is an attractive alternative to more sophisticated technologies for a number of particular applications most of all due to much less expensive implementation and simple calibration providing acceptable accuracy with sub-pixel spatial resolution. True 3-D volumetric visualization can be achieved for planar micro fluids or almost cubic flow domain at the scale of a meter. Simultaneous scalar (temperature) mapping is available for the depth of up to a few meters (industrial scale), employing as an extreme inherent high-temperature tracers (e.g. burning solid fuel particles in industrial burners/gasifiers). Appropriate applications are expected.

## References

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