XIV A.I.VE.LA. National Meeting

Correction of misalignment errors in stereoscopic PIV systems

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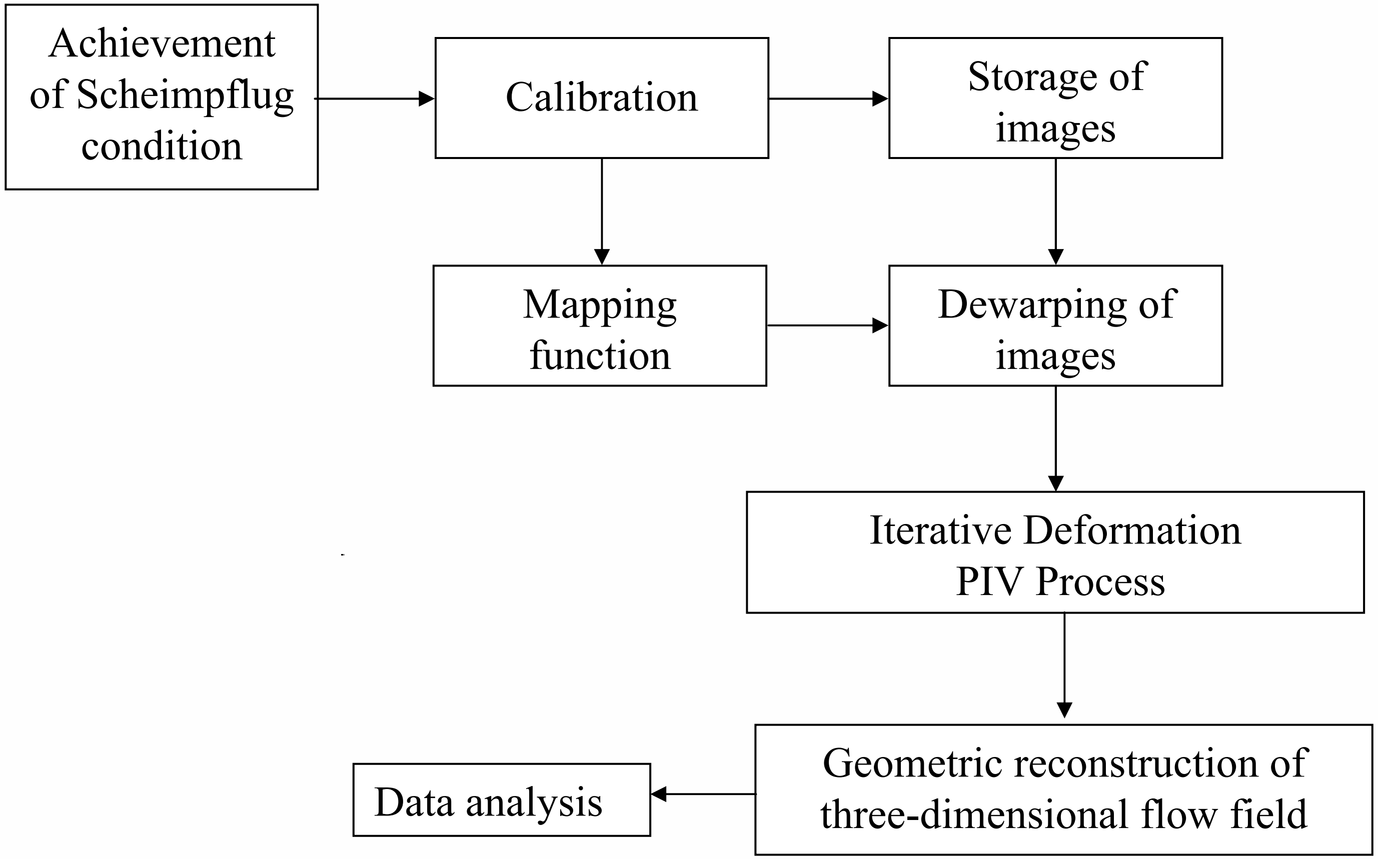
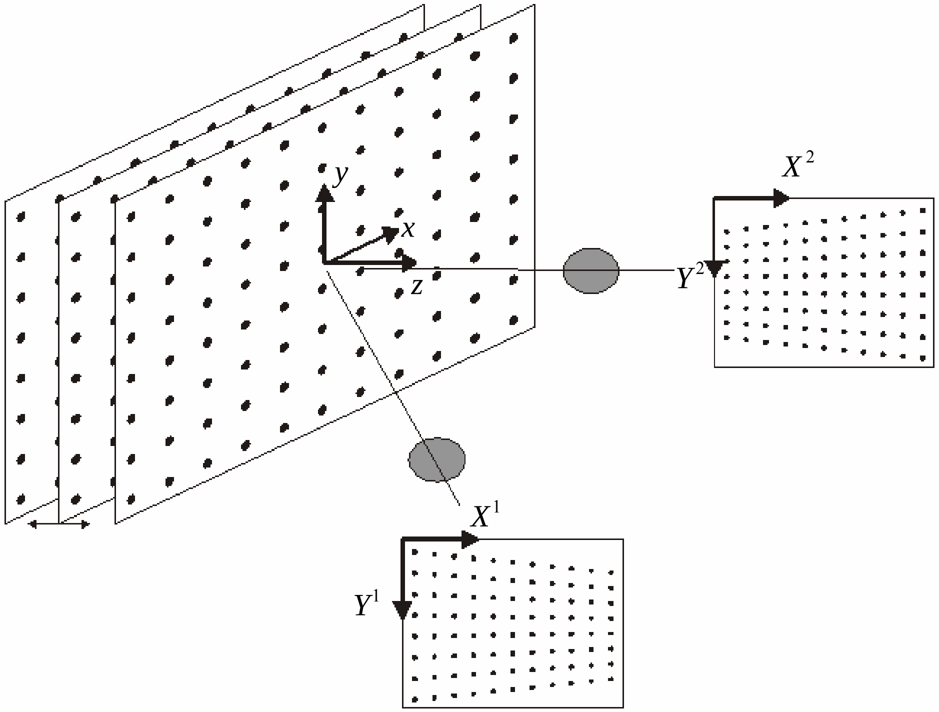
OUTLINE

- Introduction on Stereo PIV technique
- Correction of formulae to compute viewing angles
- Correction of misalignment errors
- Experimental results
- Conclusions

STEREOPIV PROCEDURE WITH GEOMETRIC RECONSTRUCTION



CALIBRATION



An interpolating function from object to image coordinates is used:

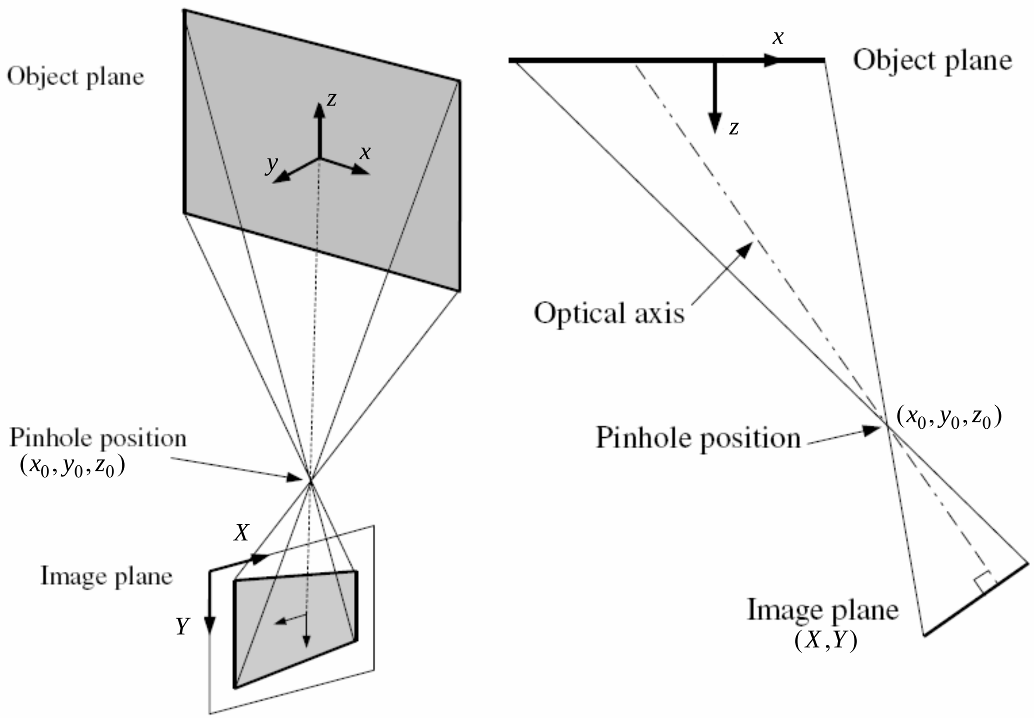
$$\overline{X} = \overline{F}(\overline{x})$$

With:

$$\overline{X} = \begin{pmatrix} X^1 \\ Y^1 \\ X^2 \\ Y^2 \end{pmatrix} \quad , \quad \overline{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

Coefficients of mapping function are calculated with the least squares method.

CALIBRATION WITH *CAMERA PINHOLE MODEL*



The model consists of 6 *extrinsic* parameters which describe the camera pinhole orientation and position in the object space, and of 6 *intrinsic* parameters, which are specific to the camera itself:

- s_x pixel aspect ratio
- k_1 and k_2 radial distortion factors (first and second order)
- f focal length
- (u_0,v_0) intersection of the optical axis with the image plane

CALIBRATION: DIFFERENT INTERPOLATING FUNCTIONS USED

In this work, following interpolating models have been analysed:

P332

$$\hat{F}(\underline{x}) = a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5xy + a_6y^2 + a_7xz + a_8yz + a_9z^2 + a_{10}x^3 + a_{11}x^2y + a_{12}xy^2 + a_{13}y^3 + a_{14}x^2z + a_{15}xyz + a_{16}y^2z + a_{17}xz^2 + a_{18}yz^2$$

P333

$$\hat{F}(\underline{x}) = a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5xy + a_6y^2 + a_7xz + a_8yz + a_9z^2 + a_{10}x^3 + a_{11}x^2y + a_{12}xy^2 + a_{13}y^3 + a_{14}x^2z + a_{15}xyz + a_{16}y^2z + a_{17}xz^2 + a_{18}yz^2 + a_{19}z^3$$

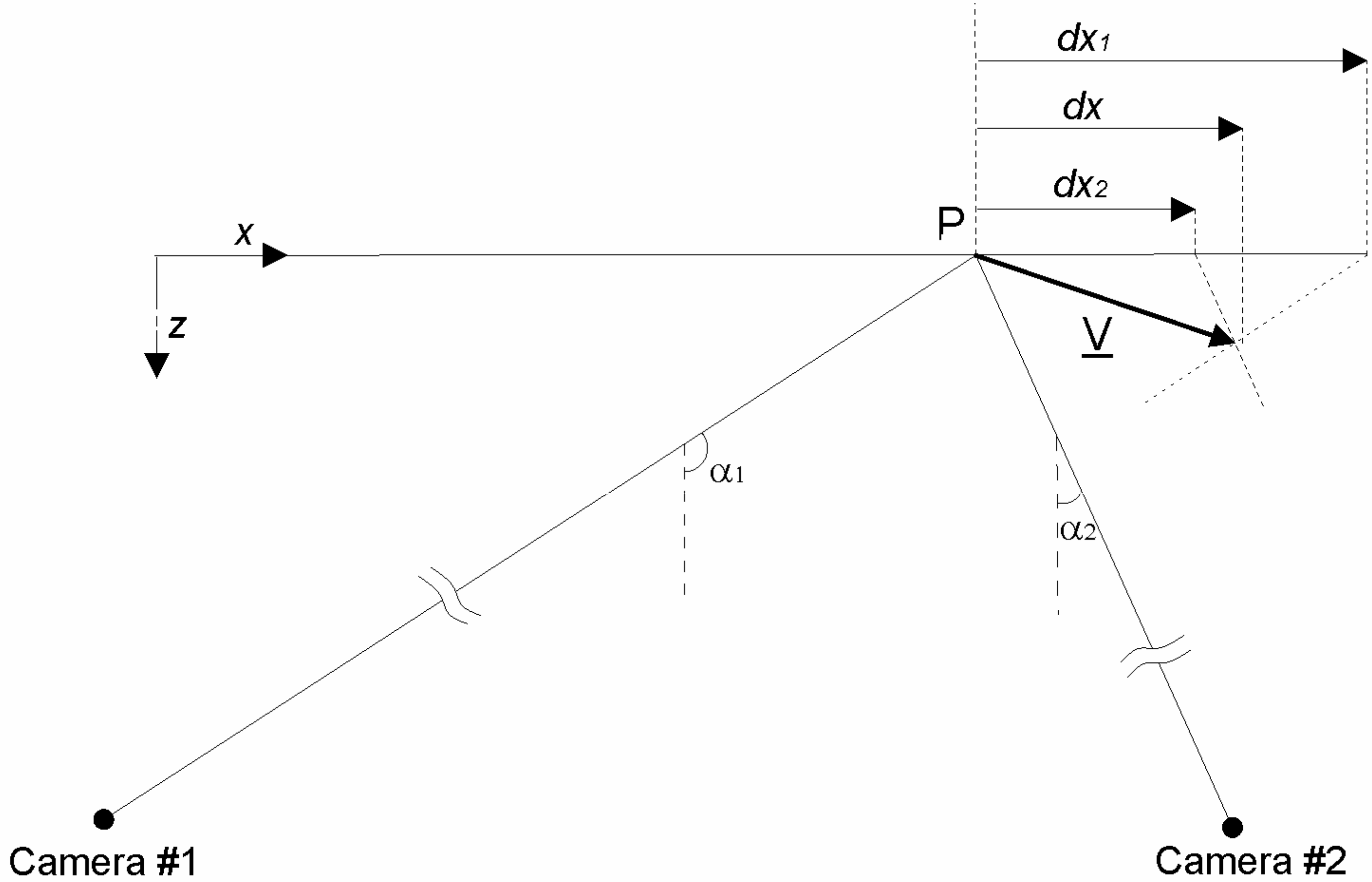
R222

$$\hat{F}(\underline{x}) = \frac{a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5xy + a_6y^2 + a_7xz + a_8yz + a_9z^2}{1 + a_{10}x + a_{11}y + a_{12}z + a_{13}x^2 + a_{14}xy + a_{15}y^2 + a_{16}xz + a_{17}yz + a_{18}z^2}$$

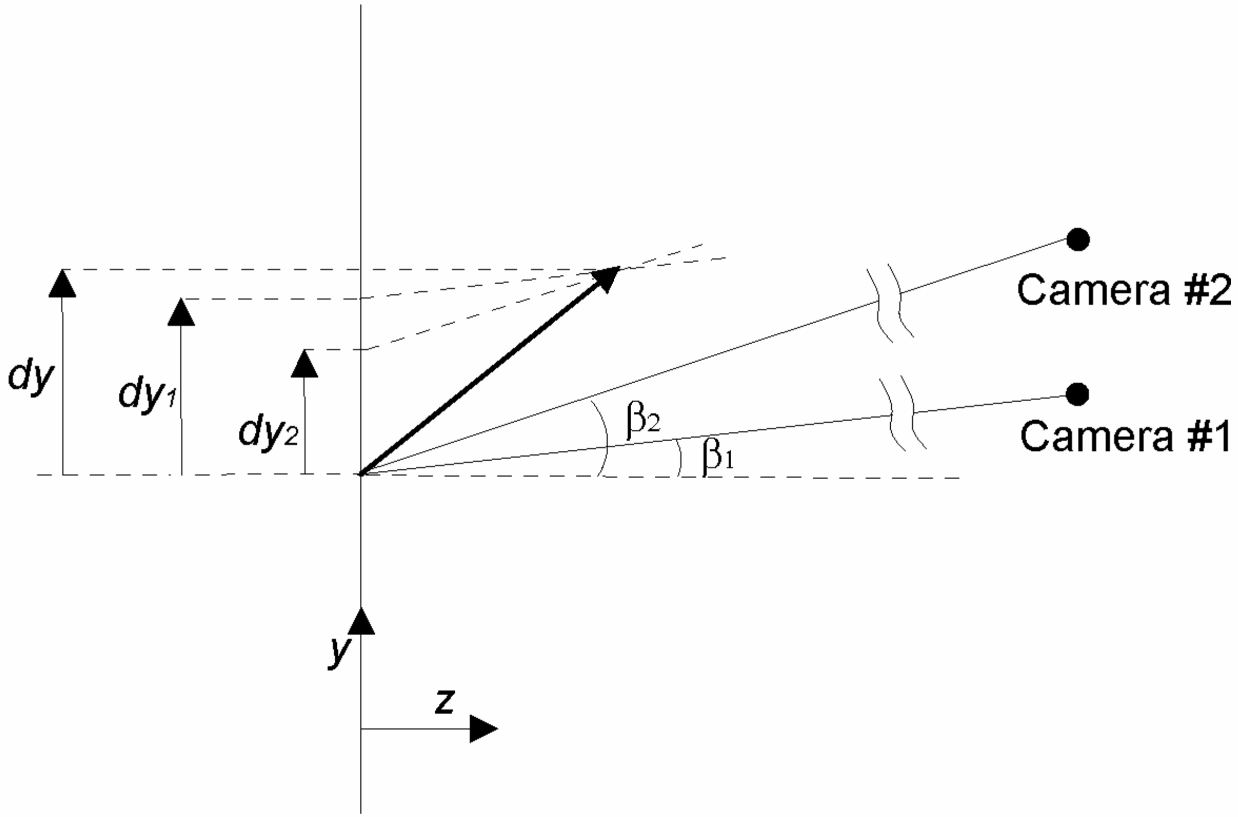
R111

$$\hat{F}(\underline{x}) = \frac{a_0 + a_1x + a_2y + a_3z}{1 + a_4x + a_5y + a_6z}$$

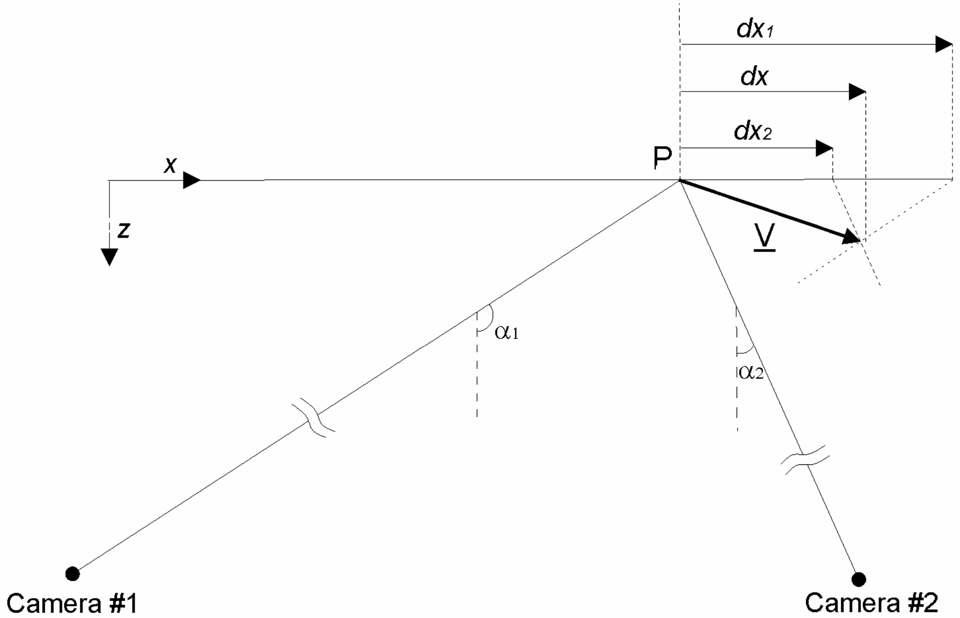
RECONSTRUCTION OF FLOW FIELD

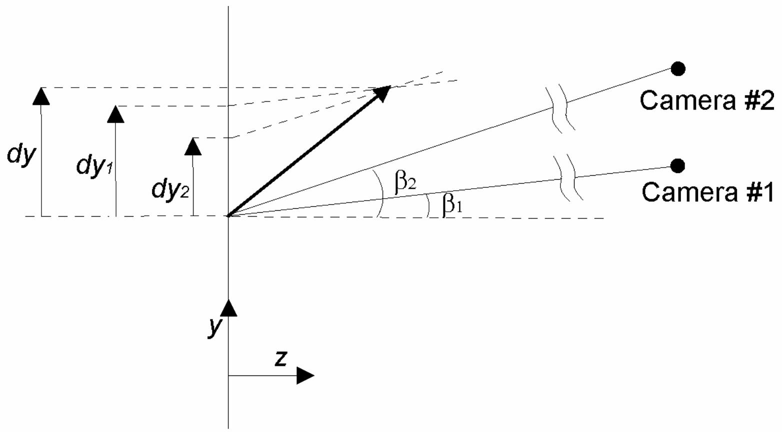


RECONSTRUCTION OF FLOW FIELD



RECONSTRUCTION OF FLOW FIELD





$$dx = \frac{dx_1 tg\alpha_2 - dx_2 tg\alpha_1}{tg\alpha_2 - tg\alpha_1}$$

$$dz = \frac{dx_1 - dx_2}{tg\alpha_2 - tg\alpha_1} = \frac{dy_1 - dy_2}{tg\beta_2 - tg\beta_1}$$

$$dy = \frac{dy_1 tg\beta_2 - dy_2 tg\beta_1}{tg\beta_2 - tg\beta_1} = $$

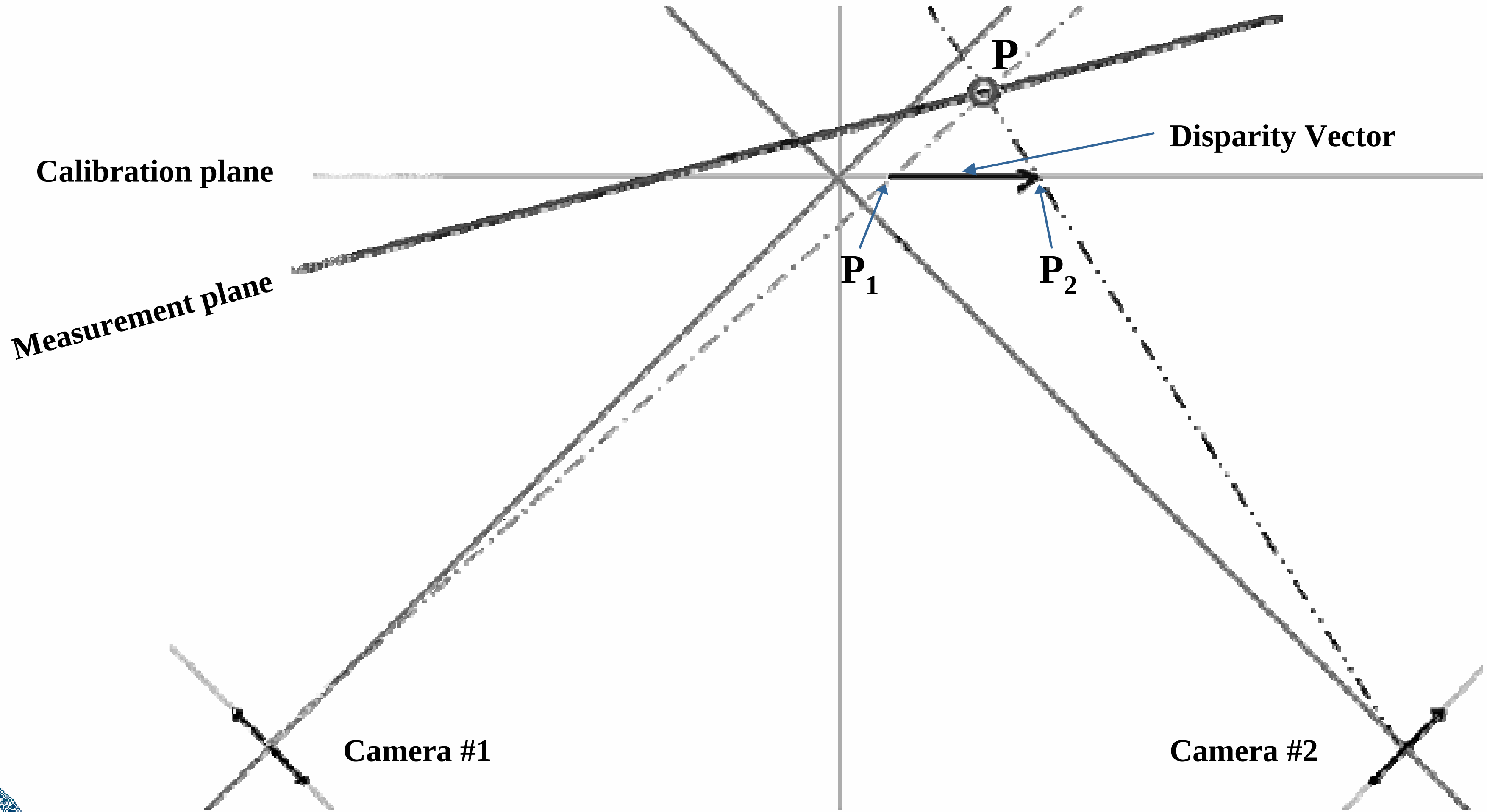
$$= \frac{dy_1 + dy_2}{2} + \frac{dz}{2}\left(tg\beta_1 + tg\beta_2\right)$$

With:

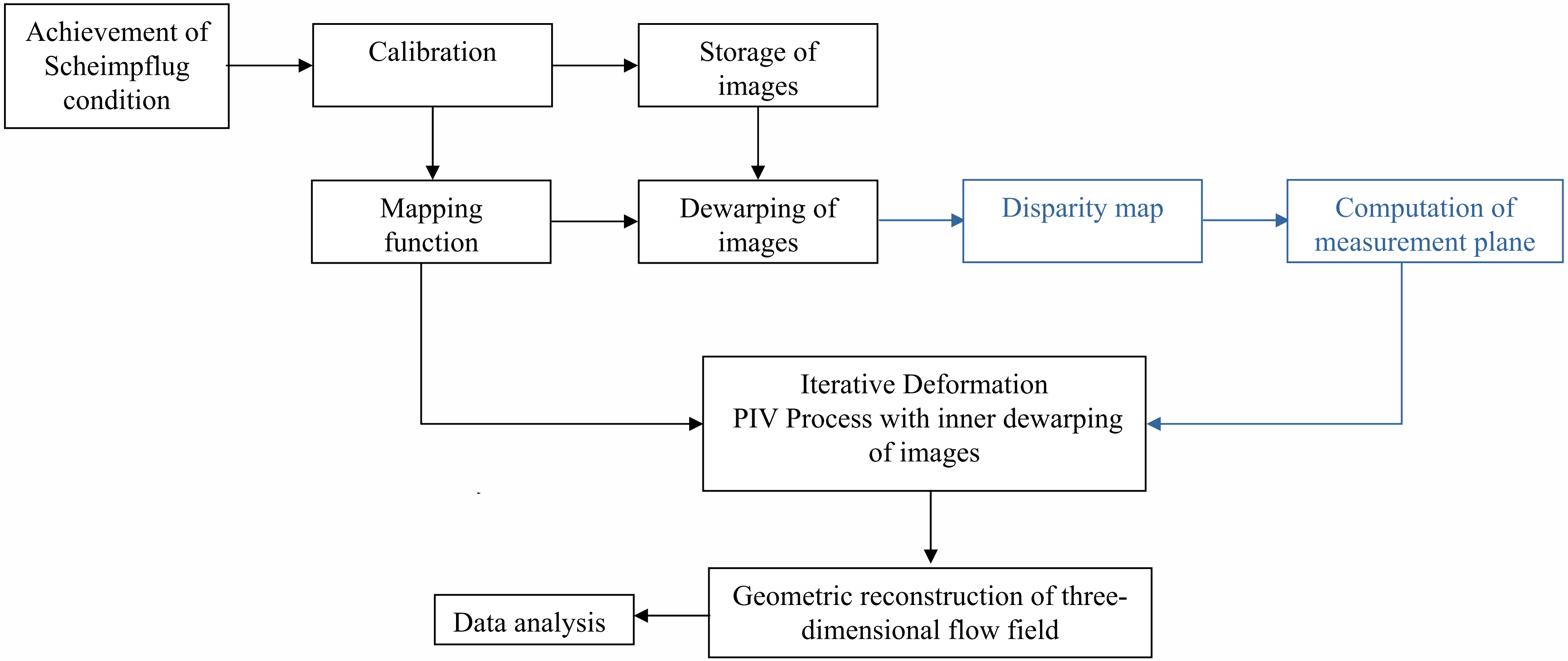
$$\tan(\alpha_{1,2}) = \frac{dx}{dz} = \frac{X_z^{1,2}}{X_x^{1,2}}$$

$$\tan(\beta_{1,2}) = \frac{dy}{dz} = \frac{Y_z^{1,2}}{Y_y^{1,2}}$$

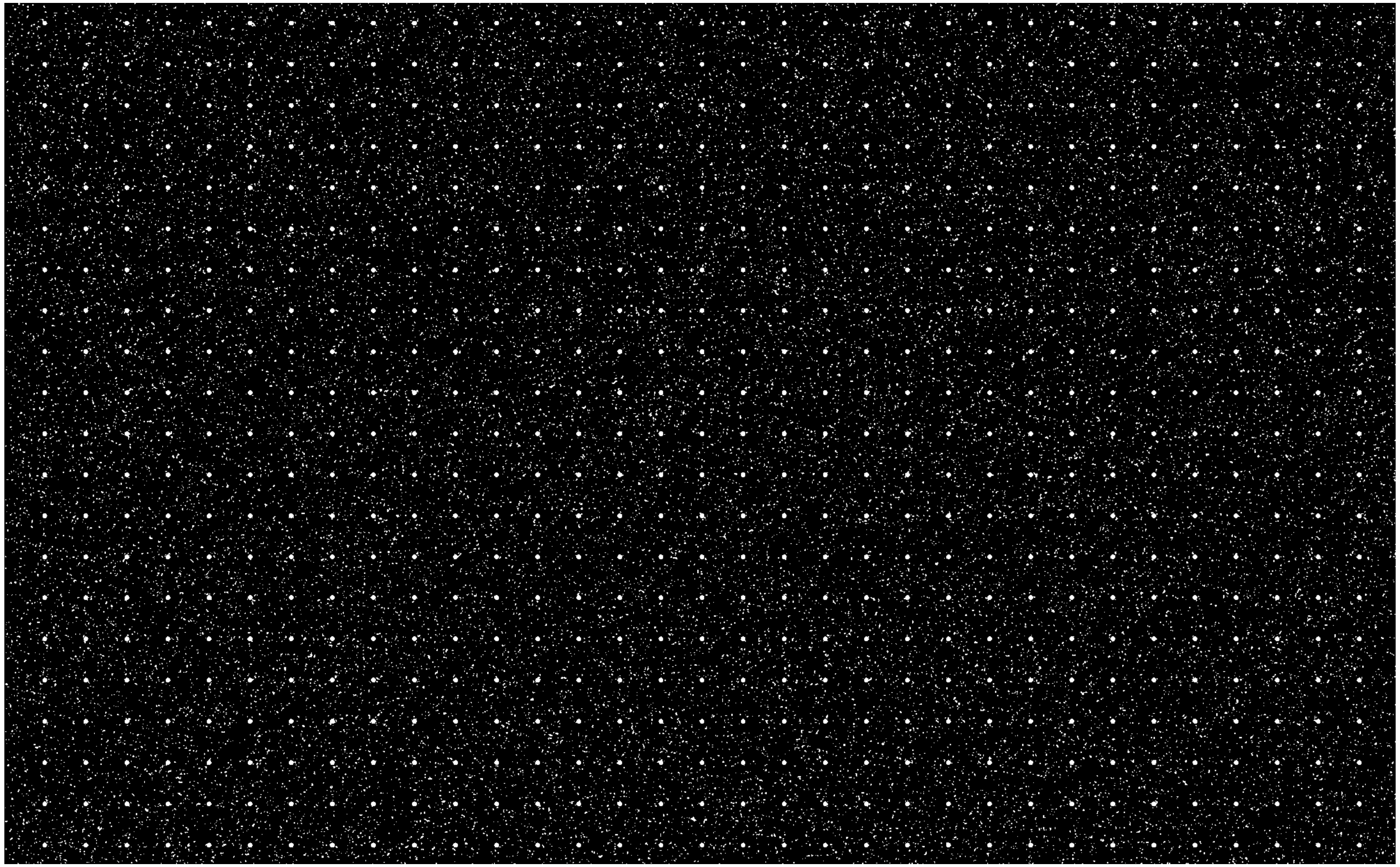
MISALIGNMENT ERRORS



STEREOPIV PROCEDURE PROPOSED TO CORRECT MISALIGNMENT ERRORS



EXPERIMENTAL RESULTS



The same pattern has been used to perform the calibration and to simulate the flow field.

Results of calibration with 3 planes using CPM, P332, R222,R11

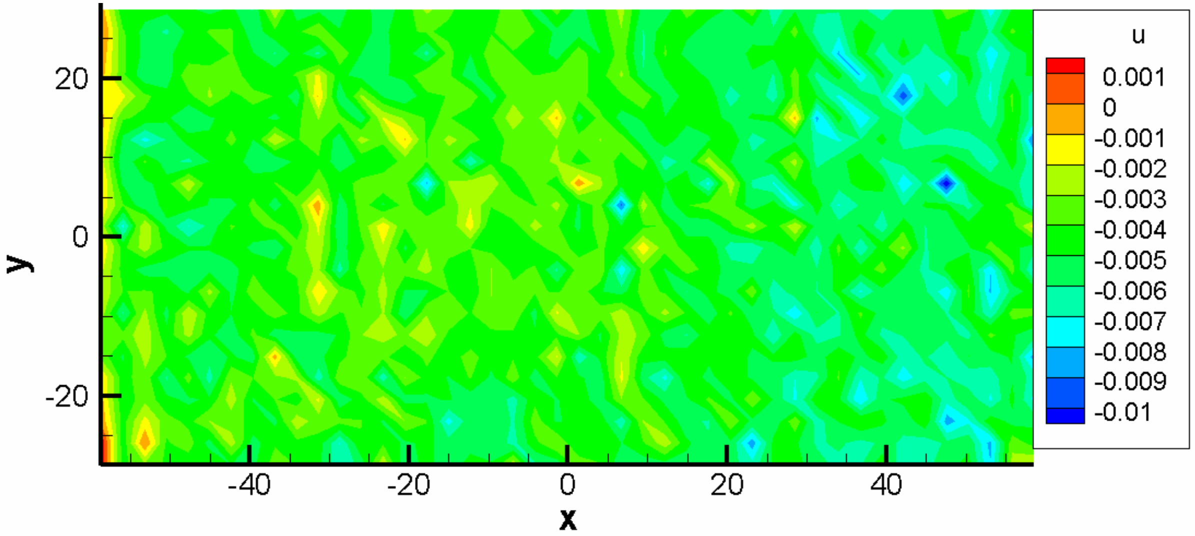
Interpolating method	RMS Cam 0 - Cam 1		MAX ERROR Cam 0 - Cam 1		R-SQUARE Cam 0 - Cam 1	
CPM	0.3992	0.4044	1.374	1.303		
P332	0.2924	0.2705	1.038	0.9807	0.9992	0.9981
R222	0.2942	0.2712	1.014	0.9860	0.9993	0.9982
R111	0.3865	0.3914	1.430	1.192	0.9952	0.9998

Results of calibration with 5 planes using CPM, P332, P333, R222,R11

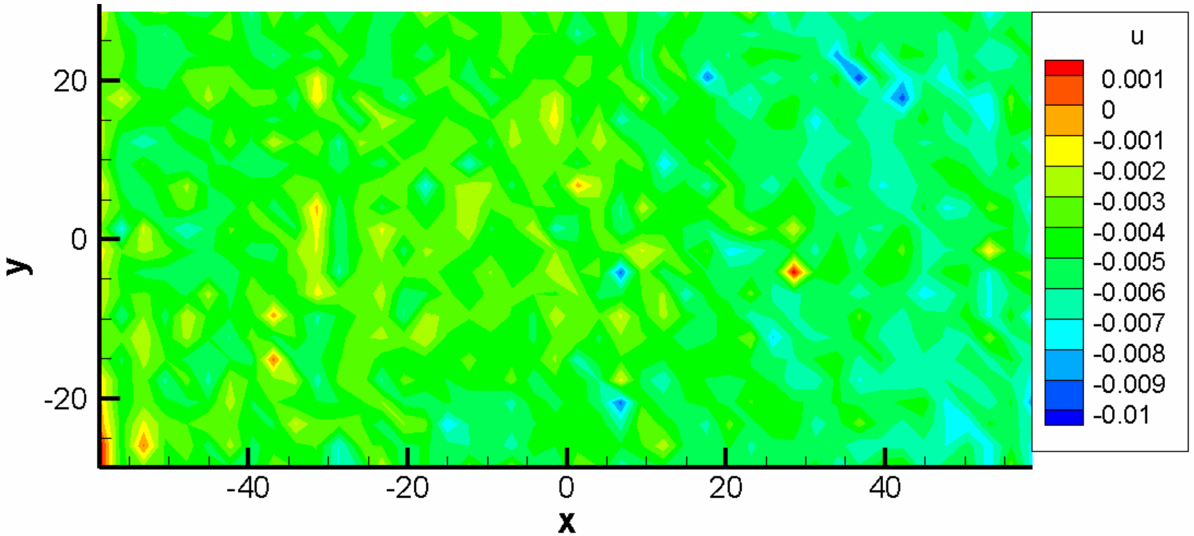
Interpolating method	RMS Cam 0 - Cam 1		MAX ERROR Cam 0 - Cam 1		R-SQUARE Cam 0 - Cam 1	
CPM	0.3954	0.4023	1.377	1.305		
P332	0.29291	0.27363	1.0477	0.96953	0.99818	0.99804
P333	0.29233	0.27206	1.0453	0.96814	0.99834	0.99819
R222	0.29464	0.27425	1.0866	0.9751	0.99792	0.99816
R111	0.38584	0.3935	1.4197	1.1969	0.99701	0.99969

Uniform flow field along z (w = 1*mm*) without misalignment: correction of the formulae to compute viewing angles

u component of flow field



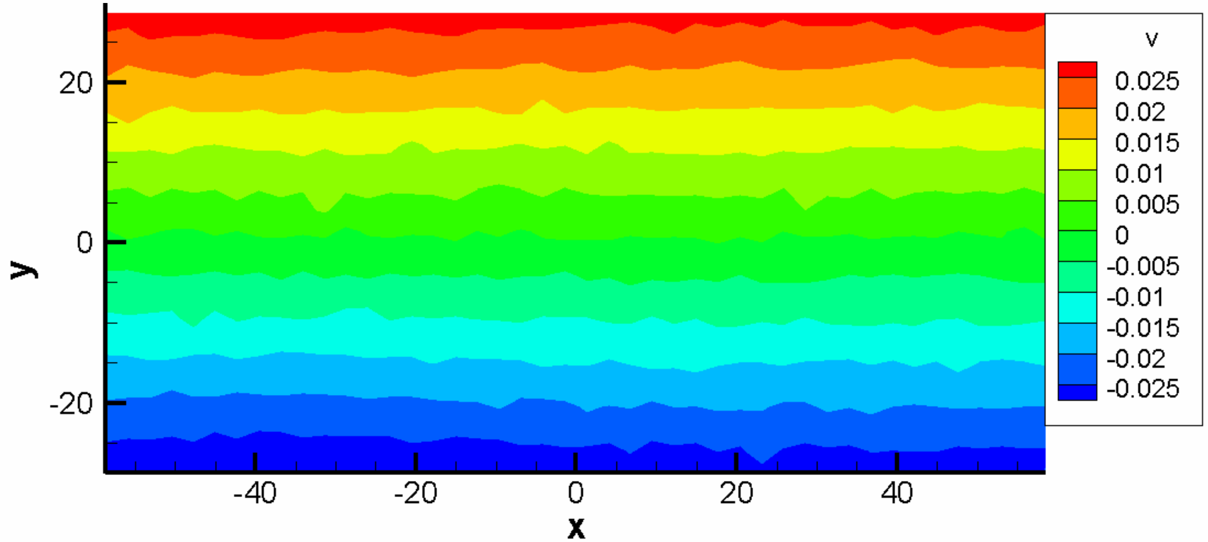
First order formulae



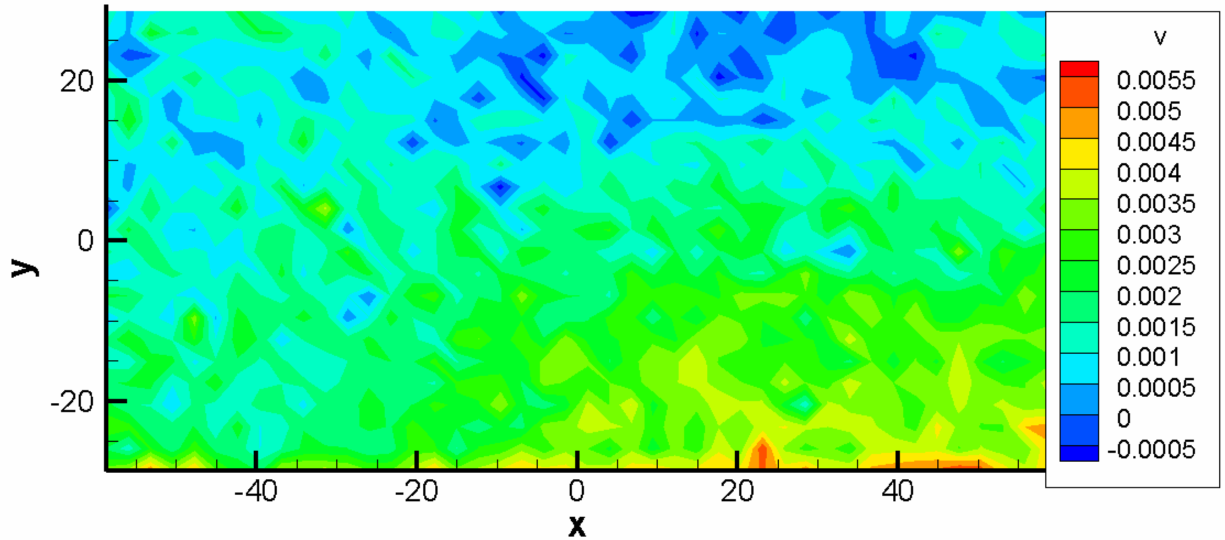
Second order formulae

Uniform flow field along z (w = 1*mm*) without misalignment: correction of the formulae to compute viewing angles

v component of flow field



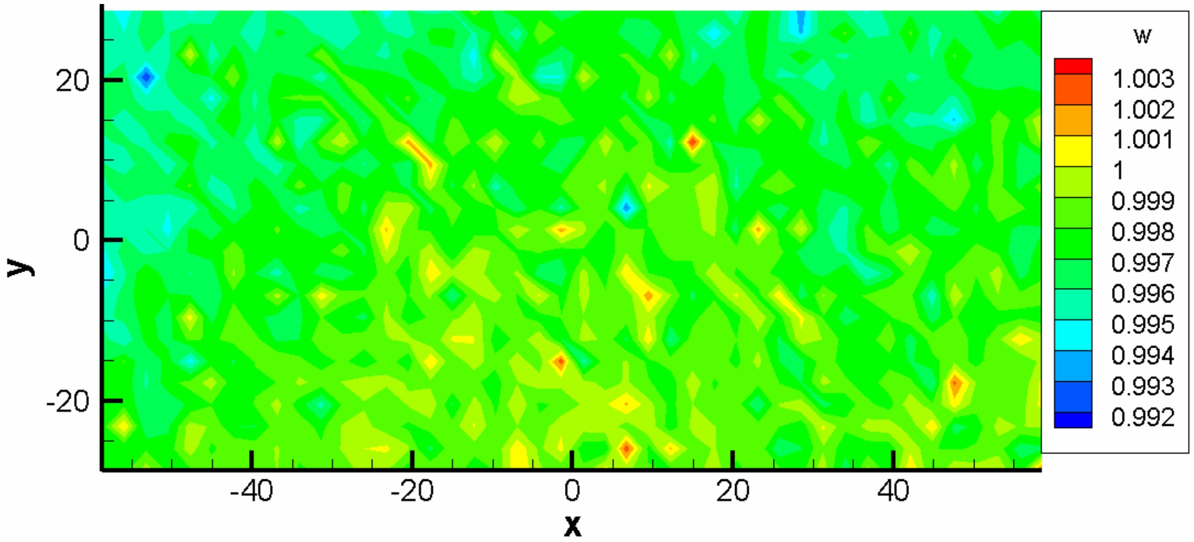
First order formulae



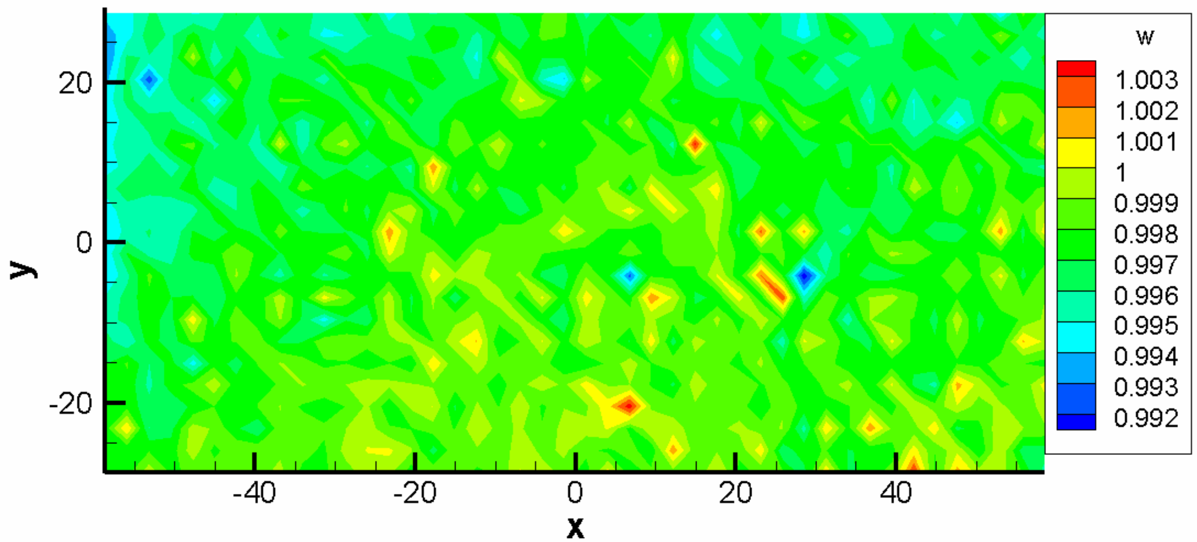
Second order formulae

Uniform flow field along z (w = 1*mm*) without misalignment: correction of the formulae to compute viewing angles

w component of flow field



First order formulae



Second order formulae

Uniform flow field along x (u′=1*mm*) with angular misalignment α=-1°: correction of flow field using the *disparity map*

$$z = 9.20e-002 \boxed{-1.69e-002} \cdot x + 9.51e-006 \cdot y$$

Equation of measurement plane obtained by means of *disparity map*

Prediction:	**u** = 0.986*mm*	**v** = 0*mm*	**w** = -0.0169*mm*

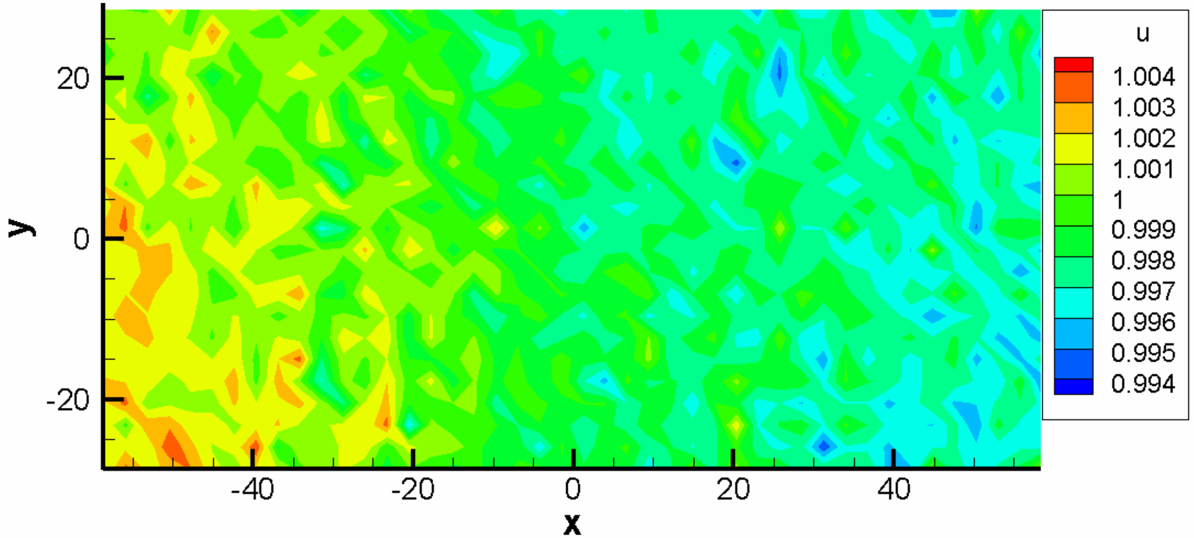
Results with disparity map

Statistics	**u** (*mm*)	**v** (*mm*)	**w** (*mm*)
Means	0.9984	-0.0005	-0.0162
Standard Deviation	0.0013	0.0009	0.0015

Results without disparity map

Statistics	**u** (*mm*)	**v** (*mm*)	**w** (*mm*)
Means	0.9988	-0.0005	-0.0330
Standard Deviation	0.0019	0.0010	0.0015

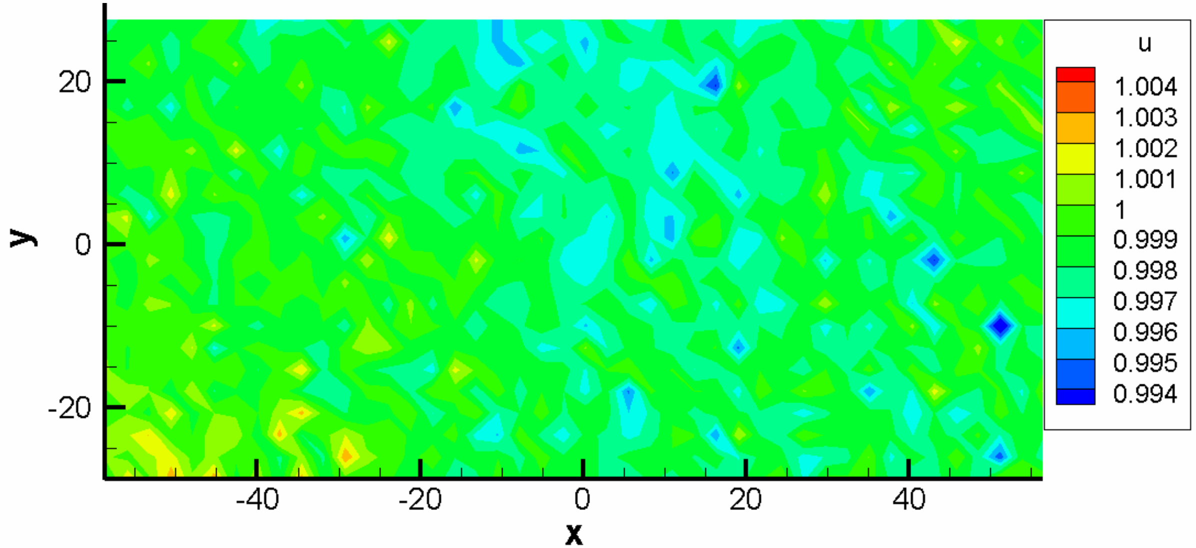
Uniform flow field along x (u′=1*mm*) with angular misalignment α=-1°: correction of flow field using the *disparity map*



u component of flow field

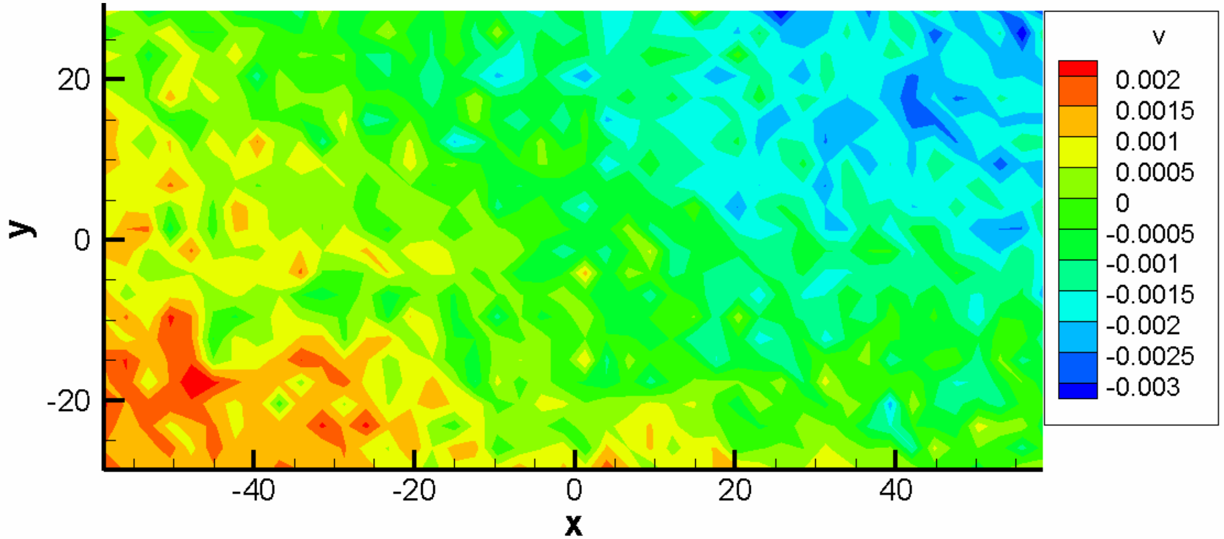
Predictor: u= 0.986*mm*

Without corrections



Corrected by means of disparity map

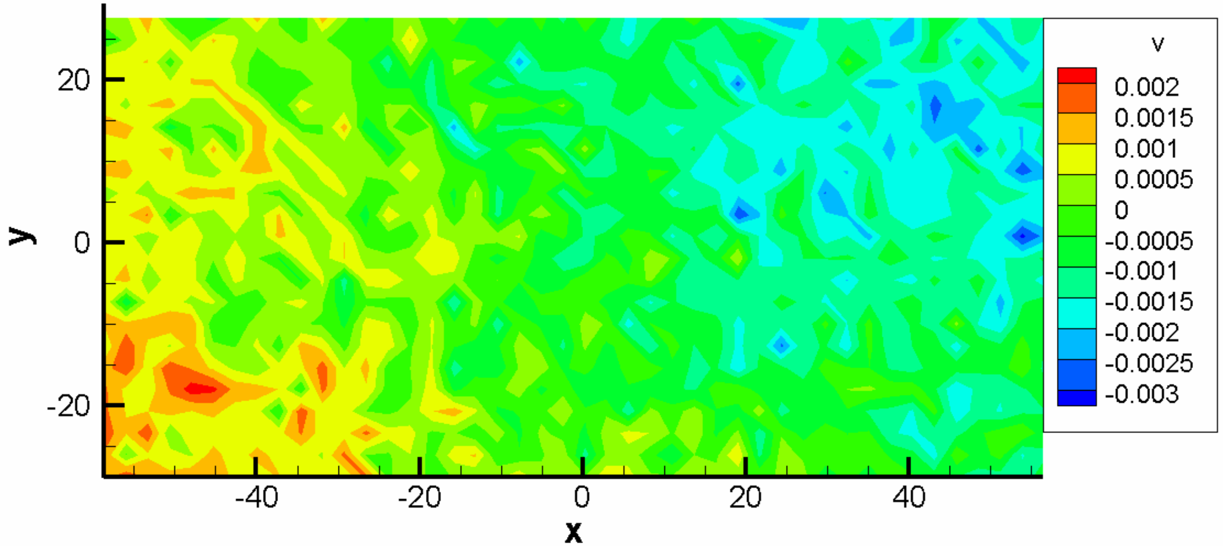
Uniform flow field along x (u′=1*mm*) with angular misalignment α=-1°: correction of flow field using the *disparity map*



v component of flow field

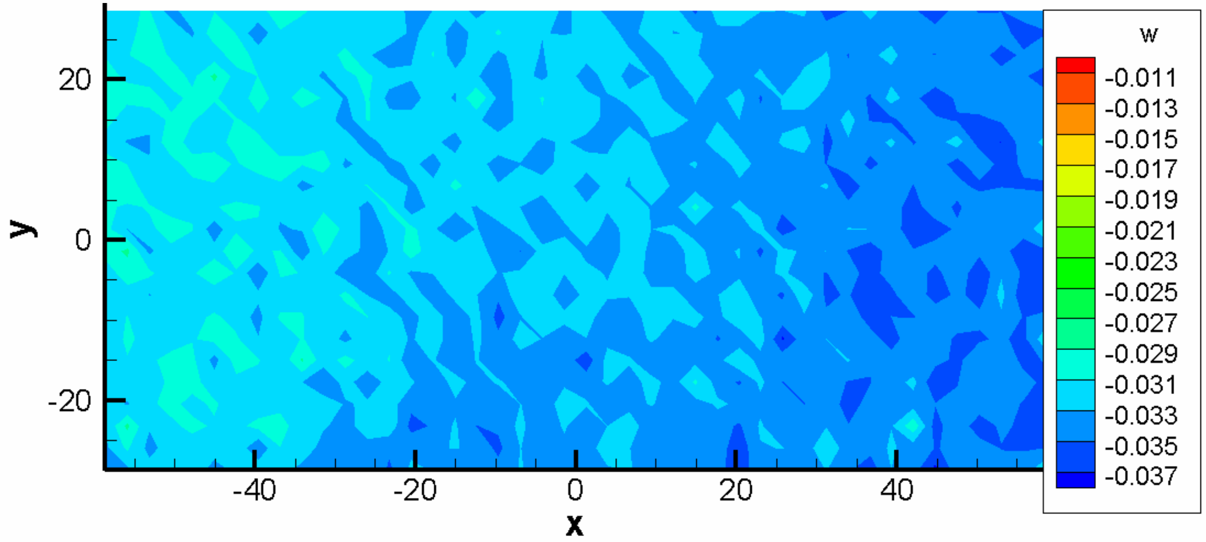
Predictor: v= 0*mm*

Without corrections



Corrected by means of disparity map

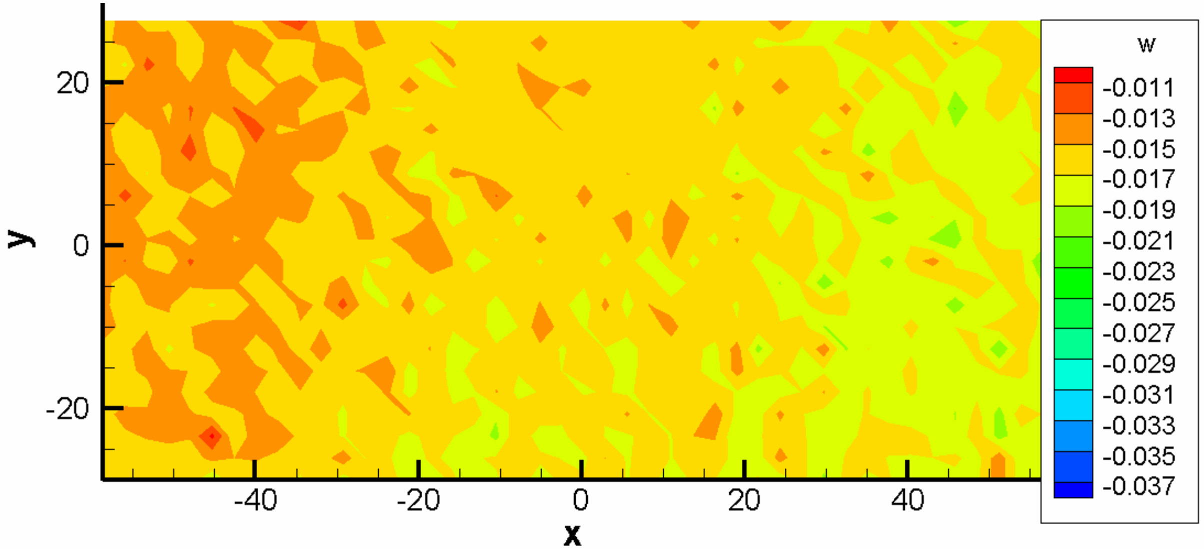
Uniform flow field along x (u′=1*mm*) with angular misalignment α=-1°: correction of flow field using the *disparity map*



w component of flow field

Predictor: w= -0.0169*mm*

Without corrections



Corrected by means of disparity map

CONCLUSIONS

A correction to calculate viewing angles has been performed.

Misalignment errors between calibration plane and measurement plane have been analysed and a correction by means of *disparity map* has been proposed.

The proposed corrections, applied to simulated flow fields, allowed to achieve an improvement in results.