DIGITAL PARTICLE IMAGE VELOCIMETRY CORRELATION ALGORITHM AT FOUCAULT-HILBERT DOMAINS

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Abstract

The modern image acquisition and processing methods are widely used at scientific and industrial applications for solving of huge number of semantically different tasks. The general structures of information technologies used for decisions making processes (DMP) at these applications are, basically, similar including three fundamental stages: visualization, image analysis, identification procedural sets. The realization of these procedures determine mostly the operation quality of whole technological chain, semantic analysis and total effectiveness of DMP at systems. The recent developing of artificial intelligence and knowledge engineering theory based on conceptions of intelligent knowledge networks prove these thesis [1]. Otherwise, this emphasizes the importance of further developing and unification of low-level (physical, logical, systematic, networking layers) methods and procedural sets based on signal and image processing. The developed, during the second half of XX century, digital Fourier- and Hilbert-optics could be recognized as the informative and very effective methodology of modern information-measuring systems design [2,3]. The publications of this article's authors also consider the aspects of physical fields visualization, image analysis, segmentation (textures fragmentation) and identification of complex shape objects'(CSO) and textures' (CST) images as structural elements of dynamic scenes [4,5,6,7]. The continuation of such research activities, by authors' opinion, is well-founded and could provide the increasing of contextually instruments' quality.

Keywords: flow visualization, particle image velocimetry, Foucault-Hilbert method.

1 Correlation techniques at Foucault-Hilbert domains

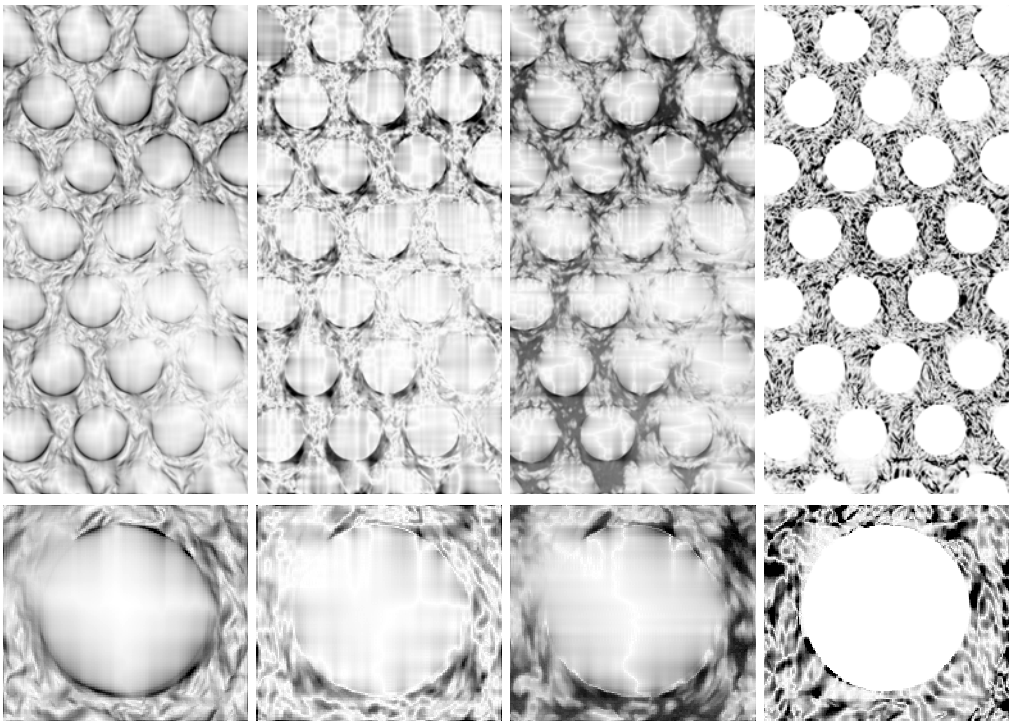
Using the Hilbert-optic methods for preliminary phase fields processing allows to increase the self-descriptiveness and accuracy of DPIV-method. Fig. 4 presents the some examples of processed images (Fig. 1, 2) at DHT and DFcT (DFcHT) domains. The next steps of DHO visualizing and estimating methods are the similar to described above. As experiments show the transferring of localization procedures to DHT (DFcT) domains decrease the cross-correlation value of adjacent sub-windows and therefore increase the accuracy of localization procedures. The classification of DHO-(Foucault-Hilbert transform algorithms and generalized amplitude-phase analysis) methods used for visualization is presented in Table 1.

Table 1: *Classification of DHO-algorithms and methods used for visualization.*

Type of transform algorithm (method)	Discrete vector transform's model
Hilbert, one-dimensional (N – length of vector $\vec{X}_N \in R$, H_N - ($N \times N$) matrix of Hilbert transformation,	$\vec{\hat{X}}_N(x) = H_N \vec{X}_N(x)$; $\vec{\hat{Y}}_N(y) = H_N \vec{Y}_N(y)$ $\vec{\hat{X}}_{Nabs}(x) = abs[H_N \vec{X}_N(x)]$; $\vec{\hat{Y}}_{Nabs}(y) = abs[H_N \vec{Y}_N(y)]$

Type of transform algorithm (method)	Discrete vector transform's model
Foucault, one-dimensional, $DFcT\{X(\vec{x})\}$; $DFcT_{abs}\{X(\vec{x})\}$	$\vec{Fu}_N(x) = \vec{X}_N(x) + j\vec{\hat{X}}_N(x)$; $\vec{Fu}_{Nabs}(x) = \vec{X}_N(x) + j\vec{\hat{X}}_{Nabs}(x)$
Foucault, multidimensional, isotropic - $DIFcT\{\vec{X}_{\vec{N}}(\vec{x})\}$;$DIFcT_{abs}\{\vec{X}_{\vec{N}}(\vec{x})\}$ anisotropic - $DAFcT\{\vec{X}_{\vec{N}}(\vec{x})\}$; $DAFcT_{abs}\{X(\vec{x})\}$	$\vec{Fu}_{\vec{N}}(\vec{x}) = \vec{X}_{\vec{N}}(\vec{x}) + j\vec{\hat{X}}_{\vec{N}}(\vec{x})$; $\vec{Fu}_{\vec{N}abs}(\vec{x}) = \vec{X}_{\vec{N}}(\vec{x}) + j\vec{\hat{X}}_{\vec{N}abs}(\vec{x})$
Foucault-Hilbert, hybrid, one-dimensional ($A^2 + B^2 = 1$) $DFcHT\{X(\vec{x})\}$; $DFcHT_{abs}\{X(\vec{x})\}$;	$\vec{Fu}\vec{H}_N(x) = A\vec{X}_N(x) + jB\vec{\hat{X}}_N(x)$; $\vec{Fu}\vec{H}_{Nabs}(x) = A\vec{X}_N(x) + jB\vec{\hat{X}}_{Nabs}(x)$
Foucault -Hilbert, hybrid, multidimensional,: isotropic $DIFcHT\{X(\vec{x})\}$; $DIFcHT_{abs}\{X(\vec{x})\}$ anisotropic $DAFcHT\{X(\vec{x})\}$;$DAFcHT_{abs}\{X(\vec{x})\}$	$\vec{Fu}\vec{H}_N(\vec{x}) = A\vec{X}_N(\vec{x}) + jB\vec{\hat{X}}_N(\vec{x})$; $\vec{Fu}\vec{H}_{Nabs}(\vec{x}) = A\vec{X}_N(\vec{x}) + jB\vec{\hat{X}}_{Nabs}(\vec{x})$ ($A^2 + B^2 = 1$)

Type of transform algorithm (method)	Discrete vector transform's model
Fourier-Hilbert, hybrid, anisotropic multidimensional,: $DAFHT\{X(\vec{x})\}$	$\vec{F}\vec{H}_N(\vec{x}') = H_N^{\otimes M} \mid [F_N^{\otimes M}[\vec{X}_N(\vec{x})]] \mid$
Generalized amplitude-phase analysis method, Foucault-Hilbert, one-dimensional	
$A_N(x) = [X_N^2(x) + \hat{X}_N^2(x)]^{1/2}$; $A_{Nabs}(x) = abs[X_N(x) + \hat{X}_N(x)]$;	$\varphi_N(x) = arctg[\hat{X}_N(x) / X_N(x)]$; $\varphi_{Nabs} = arctg[\mid \hat{X}_N(x) \mid / \mid X_N(x) \mid]$
Generalized amplitude-phase analysis method, Foucault-Hilbert, multidimensional	
$A_{\vec{N}}^{(1)}(\vec{x}) = \{\sum_{i=1}^{M}[X_{N_i}^2(x_i) + \hat{X}_{N_i}^2(x_i)]\}^{1/2}$; $A_{\vec{N}abs}^{(1)}(\vec{x}) = \sum_{i=1}^{M} abs[X_{N_i}(x_i) + \hat{X}_{\vec{N}}(\vec{x})]$;	$\varphi_{\vec{N}is}^{(1)}(\vec{x}) = \sum_{i=1}^{M} arctg[\hat{X}_{N_i}(x_i)] / X_{N_i}(\vec{x})]$; $\varphi_{\vec{N}is-abs}^{(1)}(\vec{x}) = \sum_{i=1}^{M} arctg[\mid \hat{X}_{N_i}(x_i) \mid / X_{N_i}(x$



a) b) c) d)

Fig. 1: *Examples of DHO-transformed liquid flows in shell-tubes heater: a) – Hilbert isotropic; b) –Hilbert anisotropic; c) – Foucault anisotropic; d) – generalized phase transform field.*

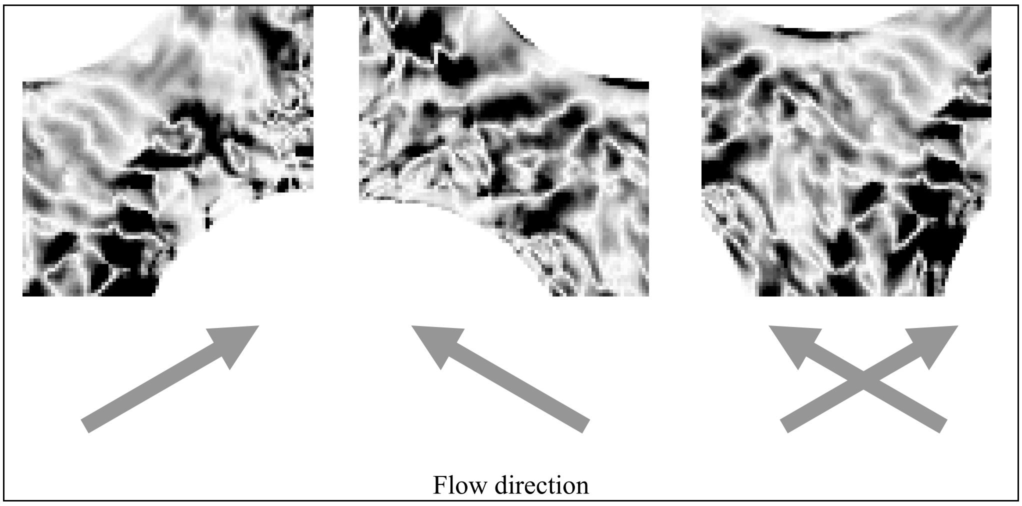


Fig. 2: *Examples of textures designed by phase analysis characteristic for flow direction.*

2 Conclusions

As the results of physical modeling, computer simulation and identification experiments the proving of real advantages of MDHO-based methods had been presented. The correlative methods at Foucault-Hilbert transforms domains increase the minuteness of visualization, accuracy of selected fragments localization and effectiveness of complex shape objects (textures) identification. The some methods realizing the suggested conception had been illustrated with processed phase images.

As the prospects of further researches the next directions could be pointed:
- comparative studying of MDHO-family contextual and effectiveness properties;
- design of real applications' problem-oriented information technologies;
- the strategies of templates' objects-oriented libraries (data bases) optimization.

3 References

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