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Phase demodulation of interferograms with open or closed fringes

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ABSTRACT Analysis of fringe patterns with partial--field and/or closed fringes is still a challenging problem that requires the development of robust methods. This paper presents a method for fringe pattern analysis with those characteristics. The method is initially introduced as a phase refinement process for computed coarse phases, as those obtained from partial--field patterns with a full-field method for open fringes analysis. Based on the phase refinement method, it is proposed a propagative scheme for phase retrieval from closed-fringe interferograms.

1. PHASE REFINEMENT METHOD

The phase refinement method assumes that there are available approximations of contrast, b, and phase, \psi , in the domain of interest, R (we assume in this point that R=T, but in general R \subseteq T). Such approximations can be computed using standard fringe analysis methods, for instance, the Discrete Fourier Transform based method [1]. As it is well known, such methods introduce artefacts at the borders of the image or along phase discontinuities. So that, in order to compute the true phase, f=\psi +\phi, we need to estimate a residual phase, \phi. Now, we suppose that \psi is close enough to f such that the first order Taylor series approximates very well the model, i.e.

$$E(\phi_r) \stackrel{def}{=} \hat{g}_r - \hat{b}_r(\cos\psi_r + \phi_r \sin\psi_r) \approx 0. \tag{1}$$

Therefore, we propose to compute the residual phase, \phi , and an outlier detector field, w, as the minimizers of the regularized half-quadratic [4] cost function:

$$\begin{aligned} U_1(\phi, \omega; \psi) &= \sum_{r\in R} \omega_r^2 E^2(\phi_r) + \mu\,(1-\omega_r)^2 \\ &\quad + \lambda \sum_{\langle q,r,s\rangle \in R} \left[(\phi_q+\psi_q) - 2\,(\phi_r+\psi_r) + (\phi_s+\psi_s)\right]^2, \end{aligned} \tag{2}$$

2. CLOSED-FRINGE INTERFEROGRAMS ANALYSIS

Now, we extend the refinement phase method for analyzing closed--fringe interferograms. Initially, the seed phase, \psi, is available for a small compact region, R, of the interferogram (note that R \subset T). Then we define the region S that contains the pixels located in a narrow band (with width defined by d) around R:

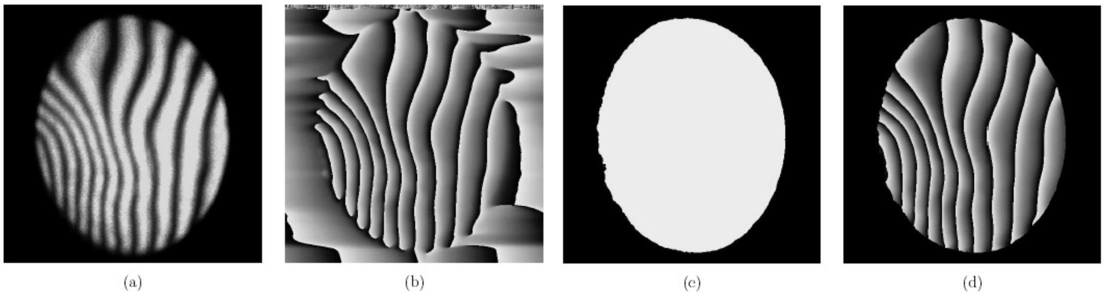

Fig.1. Phase refinement: (a) fringe pattern, (b) approximated phase, (c) mask and (d) computed refined phase. The phases in (b) and (d) are rewrapped for display purposes.

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An initial phase \psi in R can be computed with a method for opened--fringe patterns in a small region with such characteristics. Once the initial conditions are established (\psi, \phi=0, R and S), we compute and propagate the phase using again an iterative strategy of two steps. In the first step, we refine of the phase \psi + \phi in R. Then, we grow R in, at least, one pixel in the second step. The phase refinement is achieved using the previously presented method [based on (2)]. As it is known, RPT [3][4] may produce a wrong phase due to an unsuccessful normalization of the fringe pattern. In our approach, the grown pixels are chosen such that they minimize the risk of growing a wrong phase.

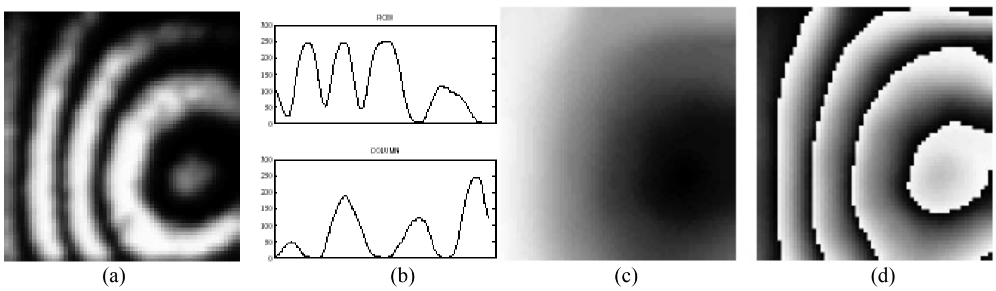

Fig. 2. Closed fringe analysis. (a) Fringe pattern. (b) Gray scale plot of the row (top) and the column (bottom) that crossing at the fringe center. (c) Computed phase. (d) Rewrapped phase, for display purposes.

BIBLIOGRAPHY

[1] M. Takeda, H. Ina and S. Kobayashi, ``Fourier—transform method of fringe--pattern analysis for computer--based topography and interferometry," J. Opt. Soc. Am. A, 4, 156-160 (1982).

[2] M. Rivera and J.L. Marroquin, `` Half--quadratic cost functions with granularity control," Image Vision Comput. 21, 345(2003).

[3] M. Servin, J.L. Marroquin, F.J. Cuevas, ``Fringe-follower regularized phase tracker for demodulation of closed-fringes interferograms," J. Opt. Soc. Am. A, 18, 3, 689-695 (2001).

[4] R. Legarda--Saenz, W. Osten and W.~Jüptner, ``Improvement of the Regularized Phase Tracking Technique for the Processing of Nonnormalized Fringe Patterns ", Appl, Opt. 41, 5519-5526 (2002).