New Effective Filter in the Spatial Domain for Speckle-Noise Reduction

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We present a new method for filtering of phase fringe patterns in the spatial domain by Chebyshev polynomials of the first kind. With numerical experiments, we determined the optimal number of Chebyshev polynomials for representing the continuous components of the phase map as the sum of polynomials.

Theoretical background

Any continuous function F(x) on the interval [-1, 1] can be represented as a sum of infinite elements:

$$F(x)=\sum_{n=0}^{\infty} f_n T_n(x) \qquad (1), \text{ where}$$

$$T_n(x)=\cos\left(n\arccos x\right) \qquad (2),$$

here coefficients f_n are determined as follows:

$$f_0=\frac{1}{\pi}\int_{-1}^{1} F(x)T_0(x)\frac{dx}{\sqrt{1-x^2}} \qquad (3)$$

$$f_{n\neq 0}=\frac{2}{\pi}\int_{-1}^{1} F(x)T_n(x)\frac{dx}{\sqrt{1-x^2}} \qquad (4)$$

Test model

A computer model of a rough surface with the dimension 500×500 and pixel size Δx=10μm was chosen as an object.

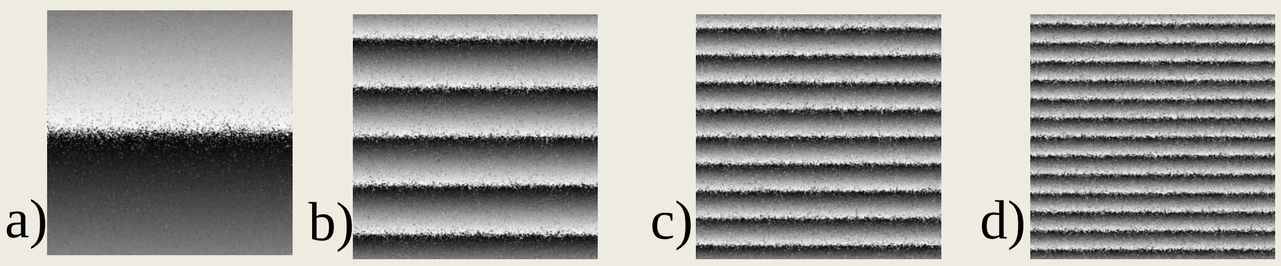

Fig.1. Example of the object deformation phase maps. Here deformation values are: a) 0.5 μm, b) 2.5 μm, c) 4.5 μm, d) 6.5 μm

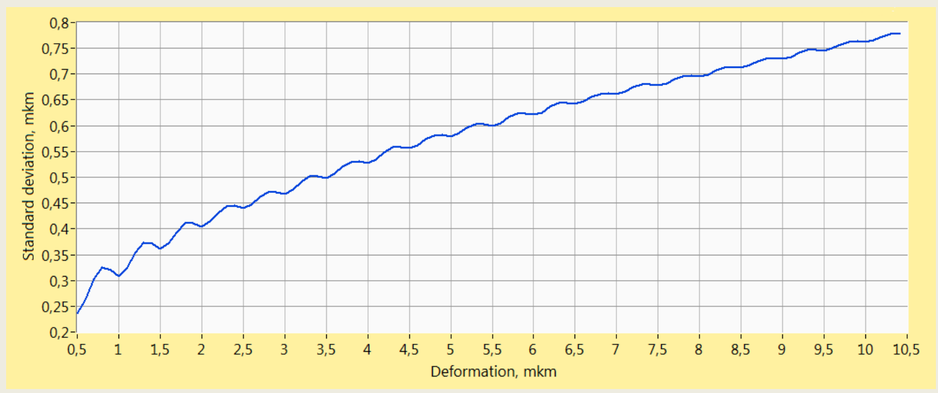

Fig.2. The dependence of the standard deviation of noise on the deformation value with pixel size p=5 μm.

Results and discussion

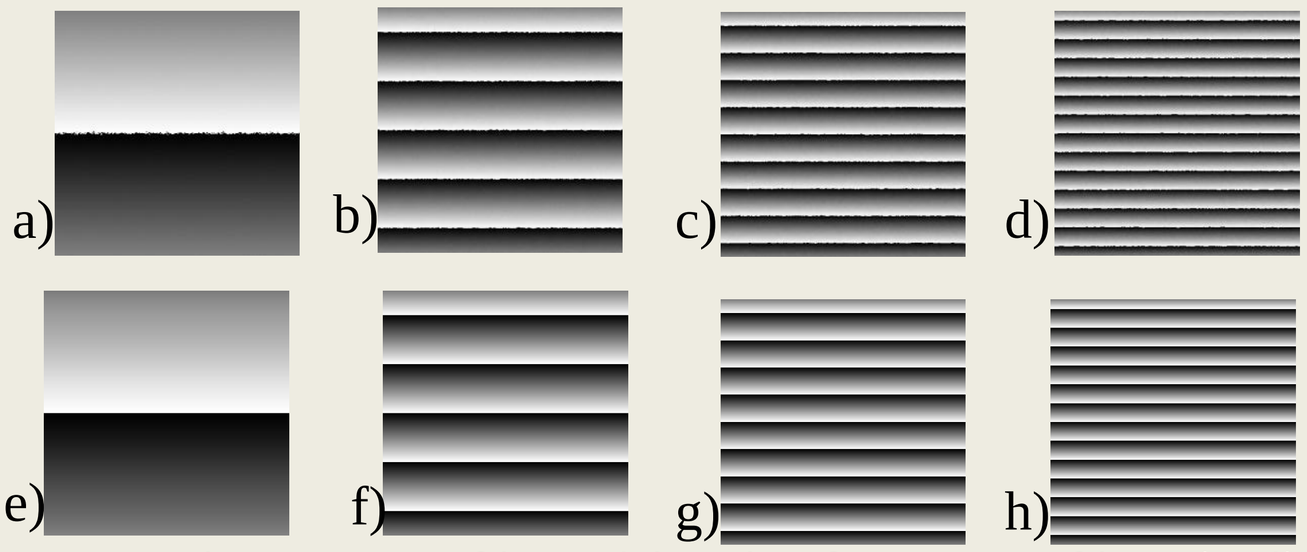

Fig.3. Phase maps filtered by the frequency filter (a-d) and Chebyshev polynomials (e-h).

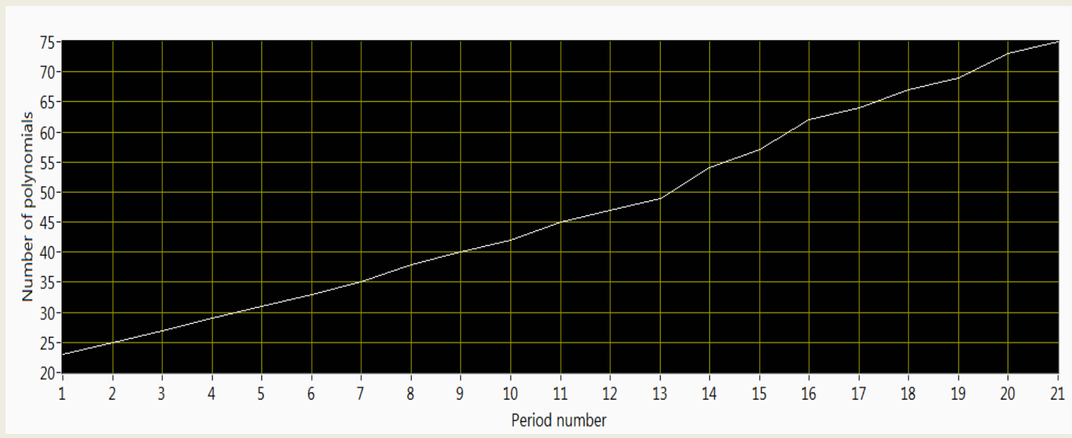

Fig.4. The dependence of the optimal number of Chebyshev polynomials on the number of a sinusoids' period.

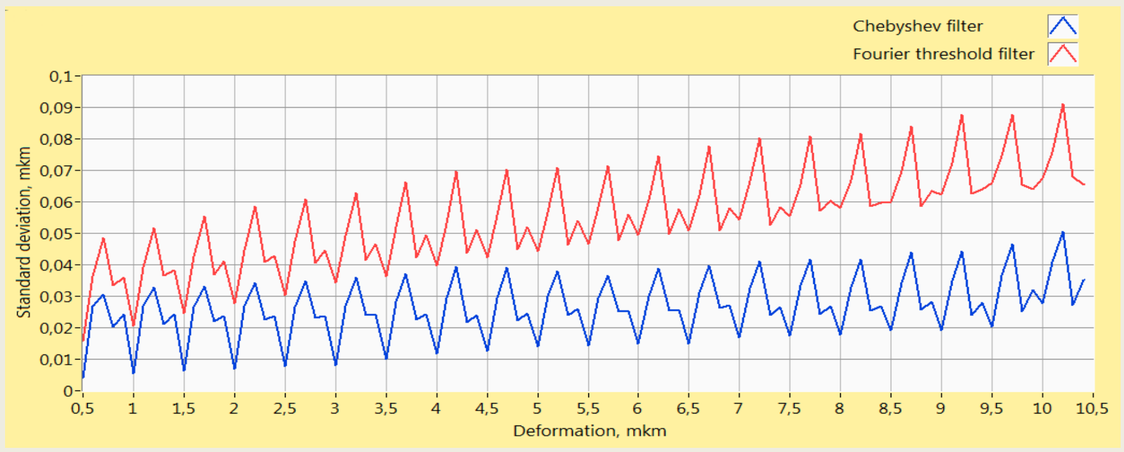

Fig.5. The dependence of the standard deviation of filtration errors on the deformation value.

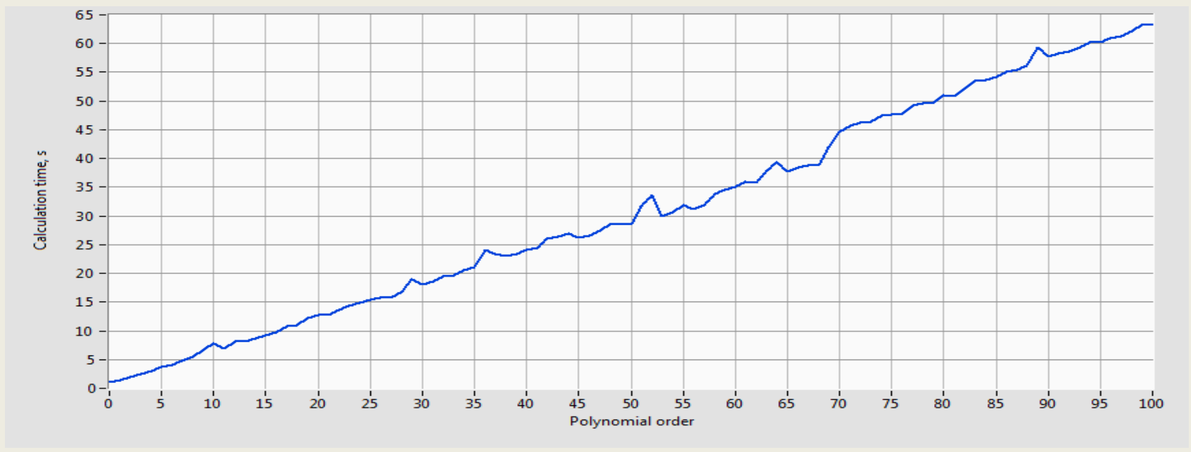

Fig.6. The dependence of calculation time on the number of polynomials (dimension 1000×1000).

Conclusion: The proposed method showed better quality and less error than the filter in the frequency domain, but it requires more processing time. However, this drawback is not so critical. The ability to cut off narrow intense peaks eliminates speckle noise even from periodic high-frequency structures avoiding distortion.