A robust phase extraction method for overcoming spectrum overlapping in shearography

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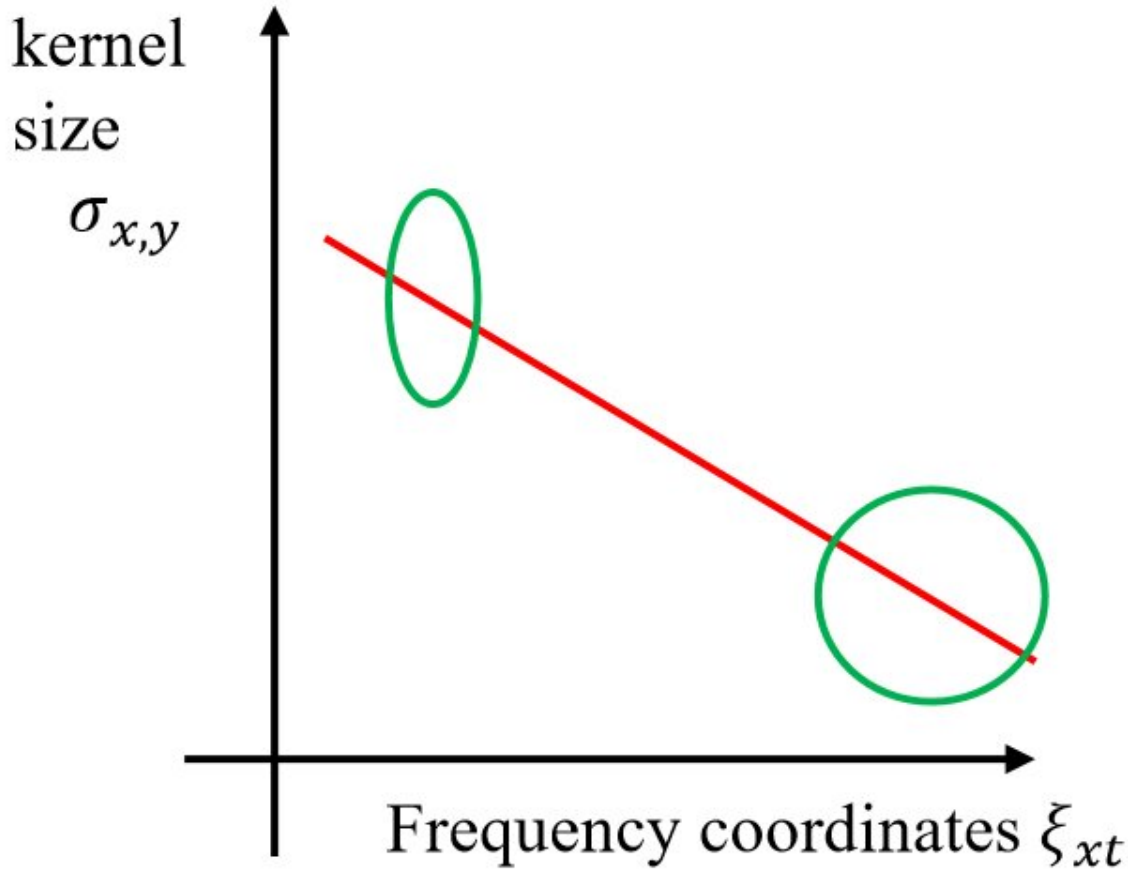

Figure 1. Credit: Yonghong Wang

In the same way as the traditional optical interference technique, shearography obtains object deformation information by obtaining the phase, and the measured object is often dynamic in practical applications, so the spatial carrier method, which can extract the phase information from a single speckle pattern, becomes a necessary phase extraction method for the practicalization of shearography. However, due to the coupling relationship between shearing amount and spatial carrier frequency, the spatial carrier method often suffers from spectrum overlapping, which seriously affects the quality of the extracted phase.

Recently, Prof. Yonghong Wang and his team from Hefei University of Technology, published a research paper in *Light: Advanced Manufacturing*, entitled "A robust phase extraction method for overcoming spectrum overlapping in shearography."

The paper reviews the causes of spectrum overlapping in spatial carrier shearography and proposes a phase extraction method based on an improved windowed Fourier ridge algorithm to achieve high quality phase extraction in spectrum overlapping. Simulations and practical experiments are conducted to verify the effectiveness of the proposed method for various cases.

In many cases, spatial carrier shearography is inevitably subject to spectrum overlapping, such as large deformation detection or large aera detection. If the phase extraction method can extract a high quality phase in the case of spectrum overlapping, it will be beneficial to the practical application of shearography.

The windowed Fourier ridge (WFR) is a phase extraction method proposed by Prof. Qian KeMao of NTU mainly for phase extraction of project fringes. However, in shearography, the spectrum overlapping produced is the most serious due to the consistency of the spectrum size of background light, object light and conjugate object light, and it also

puts forward higher requirements for the parameter setting of WFR algorithm.

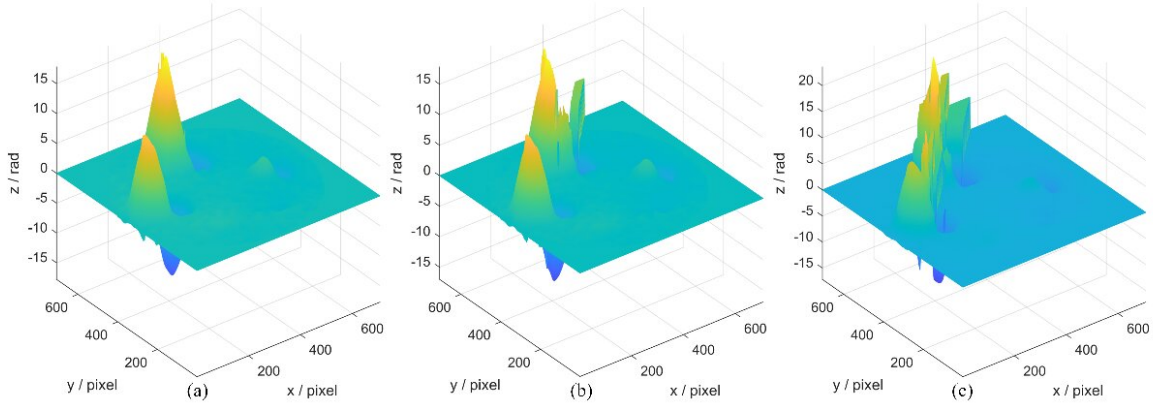

Figure 2. (a) Unwrapped phase map of the method described in this paper, (b) unwrapped phase map of the nonlinear filter, and (c) unwrapped phase map of the binary mask filter. Credit: Yonghong Wang

Since modern optical systems widely use circular aperture diaphragms, the proposed method uses the Hough transform to analyze the speckle pattern spectrum, obtains the coordinates of the center point of the object spectrum and the radius of the spectrum, and roughly determines the frequency band of the window Fourier ridge through the correspondence between the frequency domain coordinates and the spatial coordinates of the camera sensors, which reduces the running time of the algorithm and allows searching the local frequency with a smaller step size.

In addition, for the regional characteristics of the object light spectrum when the spectrum is mixed, using a large window for WFR will lead to increased speckle size, and a small window will be mixed with zero-

order information, so this paper proposes the use of a linearly transformed elliptical window for WFR, as shown in Figure 1, the elliptical window with the long axis parallel to the y-axis direction is used near the zero-frequency, and with the right shift of the frequency scan interval linearly changes to an elliptical window with the long axis parallel to the x-axis direction, thus maximizing the use of spectrum information and improving the quality of phase extraction.

The researchers obtained the speckle patterns under different spectrum overlapping cases by simulation and experiment, and also compared two other phase extraction methods. Taking the measured object as a non-destructive testing standard as an example, Figure 2 shows the real phase of the phase map obtained by the three phase extraction methods after filtering and unwrapping.

It can be seen from Figure 2 that the unwrapped phase obtained by the proposed method is very smooth, while the other two methods have obvious fringe breaks causing the unwrapped phase anomaly, which verifies the effectiveness of the proposed method.

More information: Xiangwei Liu et al, A robust phase extraction method for overcoming spectrum overlapping in shearography, *Light: Advanced Manufacturing* (2023). DOI: 10.37188/lam.2023.007

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