Automatic Analysis of Interferograms

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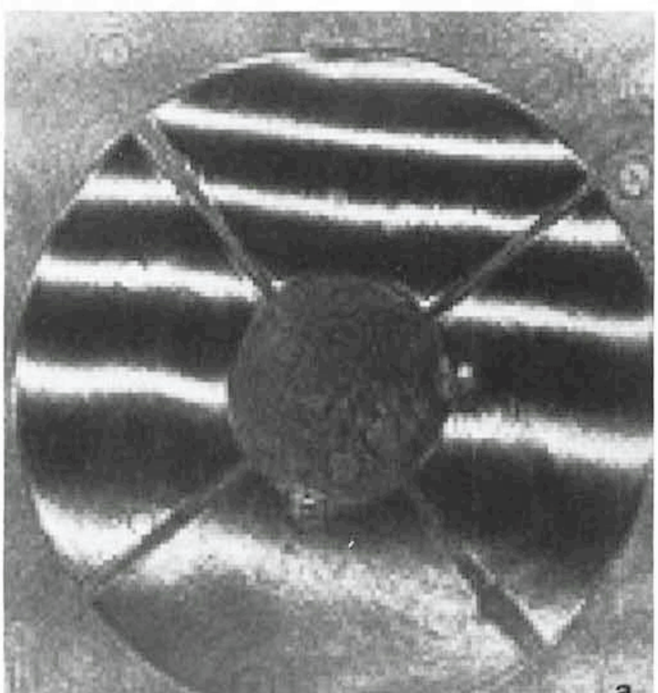
1. Introduction

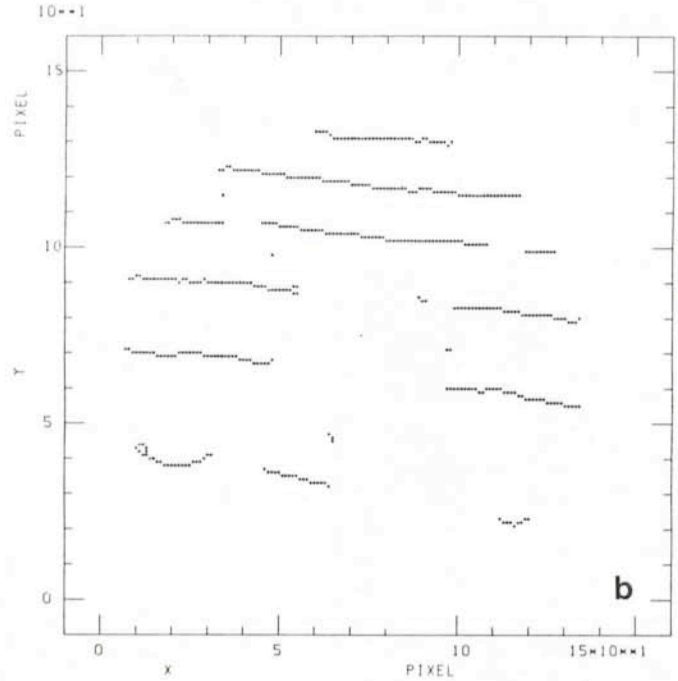
Interferometric techniques have been used in optical testing for a long time. The introduction of the laser made this method a routine procedure in the evaluation of the quality of optical components. The interpretation of interferograms is in principle very simple. The fringes represent lines of equal phase difference between two wavefronts, one of which is often flat or spherical. The height difference between two adjacent fringes is usually one wavelength of the radiation used. From the shape and relative order number of the fringes, the map representing the phase difference between the two wavefronts can be reconstructed. Using this phase map, one can then proceed to calculate the more meaningful physical quantities like refractive index variation, distance or stress. This modelling process is different for each application. At ESO, interferometry is used in the testing of optical components for instruments, and programs have been developed that fit the phase map to a set of orthogonal quasi-Zernike eigenfunctions, representing the well-known optical aberrations like spherical aberration or coma. A difficulty has always been to enter into the computer the positions and order numbers of the fringes; up to now this was done manually.

This paper briefly describes a new method of fringe analysis that reduces the manual interaction to a minimum, a more detailed explanation will be given in a forthcoming article.

2. The Method

The method consists of two main steps:
- Fringe detection
- Fringe identification and numbering





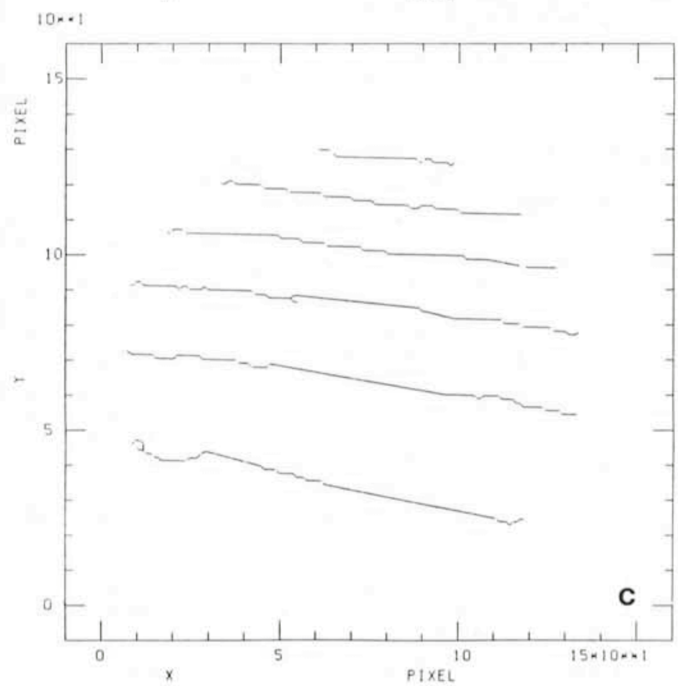


Fig. 1: *Illustration of the method. The original interferogram is shown in 1.a. The detected positions of the fringe maxima are shown in 1.b. In figure 1.c, these positions are connected by the fringe identification algorithm. In the present status of the program, only one link had to be established manually.*

The first step produces, from the original interferogram, a binary image containing information about the positions of the fringe maxima. The value of a pixel in the binary image is 1 if the pixel corresponds to a relative maximum in the original interferogram, and is 0 otherwise.

In the ideal case of a perfect interferogram, this step will be enough to analyse the fringes, and automatic methods proposed so far stop at this stage, perhaps adding a more or less complicated scheme for the numbering of the fringes. However, in real interferograms, the binary image resulting from this step contains disconnected fringe segments, with many spurious positions that were considered as fringes by the algorithm. This is the reason why the available methods do require a substantial interaction to define the numbering of the fringes.

Our method includes a second step where we introduce the information about general properties of fringes (being lines of equal phase), namely: (1) fringes do not intersect, and (2) fringes do not end inside the field of view unless they are circular. By introducing this information we have been able to define an algorithm that "recognizes" the fringes, i.e. is able to reject spurious positions and false fringes, and connects segments belonging to the same fringe. After this step the problem of numbering the fringes is almost trivial and can be done fully automatically.

Given the modularity of the implementation, it is possible to use optional steps to improve the results at any stage in the analysis. The original image can be resampled in order to reduce the image size and the computing time; different filters can be used to reduce the noise in the original interferogram; thinning algorithms will allow a better definition of the fringes in the binary image, previously to the second step.

3. Results

We are testing the method on a large sample of interferograms from which we selected one example in order to illustrate the algorithm; it is a complicated case because some fringes are cut due to the presence of an object in the field of view, and the signal-to-noise ratio is not very good. The results of the method are shown in figure 1. The image in 1.a is the original interferogram; 1.b is a diagram of the positions detected in the first step of the method, it includes spurious fringe positions and shows several fringe segments; finally, figure 1.c is the resulting interferogram, where the spurious fringes are rejected and the true fringes do obey the rules defined in the previous section.

This approach can be used not only for analysis of interferograms; similar principles are applicable to the reduction of multiple object spectra (EFOSC, OPTOPUS) and echelle spectra (CASPEC).

The method has been implemented in MIDAS as a set of commands that allow the automatic analysis of the interferograms as well as the representation of the intermediate results. This implementation opens a new field of applications, so that MIDAS can be used not only for data reduction but also in the testing and integration of new instruments.

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