

# **FAULT DETECTION THROUGH PATTERN RECOGNITION BY AN OPTOELECTRONIC HYBRID PROCESSOR**

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## **Abstract**

Interferogram based fault detection is essentially a problem of pattern recognition: Typical fringe configurations indicating mechanical defects have to be detected. For this purpose data reduction and feature extraction are necessary in order to compute the final decision. The local grating-like structure of interferograms suggests their description in terms of line spacing and orientation. To extract and evaluate these features a hybrid opto-digital processor is introduced.

## **Introduction**

Interferometric methods for non-destructive testing such as double exposure holography, time average holography etc. have been developed during the last two decades and up to now their applications were mainly restricted to experiments and prototype testing. Since the introduction of compact systems for interferometric measurements that meet industrial standards interferometry is entering the field of quality control in mass production of highly reliable parts, such as car tires etc.. In these applications an automated "good" or "bad" decision is desirable, rather than quantitative evaluation of mechanical stress or deformation.

The proposed system allows fast, easy and artefact-free data acquisition from a photographic transparency, due to the analog-optical computing principle of the preprocessor. The digital section adds the necessary flexibility to the system which is important to allow universal application, that is to compute the final decision according to any desired criterion.

## **Realization**

The experimental system, as shown in figure 1, may be divided into two blocks: The coherent-optical preprocessor and the digital control and evaluation unit.

The preprocessor illuminates the input transparency with parallel coherent light, transforms it by means of lens L1 into the fourier domain, filters it there and finally transforms it back again into the space domain with lens L2 onto the vidicon target of a TV-camera for further processing.

The heart of the preprocessor is a time-varying, two dimensional single-side bandpass filter, composed of two sandwiched diaphragms. Figure 2 shows the two diaphragms: a logarithmic spiral, selecting the absolute value  $f$  of the spatial frequency i.e. the line spacing and a sector, selecting the angular component  $\phi$  i.e. the line orientation. Each filter component is mounted on a stepping-motor driven ball bearing, independently controllable by the Z-80 microprocessor through the step

control unit. The compound filter is centered on the origin of the frequency plane, allowing the variable bandpass to successively scan the relevant frequency ranges by means of rotating the diaphragms.

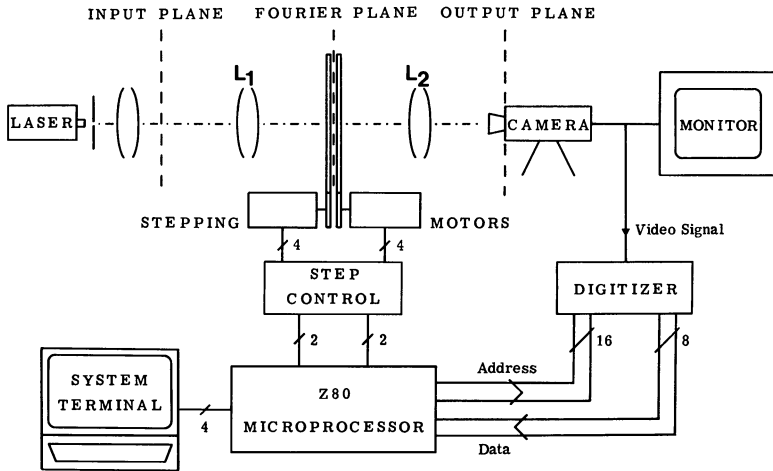


Fig. 1 Opto-electronic hybrid processor for interferogram evaluation

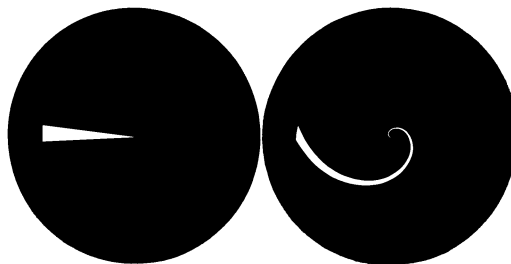
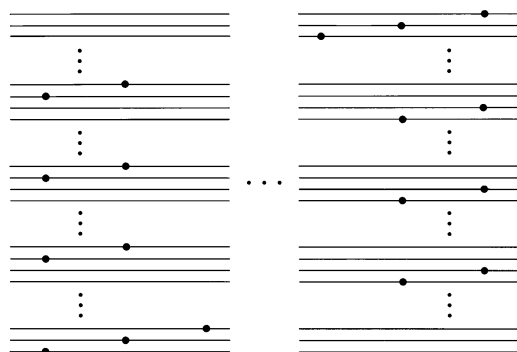


Fig. 2 Components of the time varying filter used in the coherent optical preprocessor

The output of the preprocessor is an unmodulated twodimensional intensity distribution, with high intensities in those regions where the input image has the features that correspond to the selected filterposition, i.e. a certain line spacing and orientation. Since these features are relatively constant over small regions of the input transparency, the output intensity distribution may be sampled rather coarsely. A sampling raster of only 16 x 16 equally spaced samples proved to be sufficient. Since therefore only 256 samples have to be digitized per TV-field, a simple digitizer with a low-cost 8-bit AD-converter was used for data aquisition. This digitizer is capable of addressing 256 picture elements in 256 lines. It is therefore possible to take only one sample per TV-line if the sampling scheme as shown in figure 3 is employed.



**Fig. 3** Low resolution sampling scheme for TV-images, one sample per TV-line

This scheme gives the microprocessor almost 64 microseconds of time between two consecutive samples, enough to calculate the address of the next sample point, trigger the ADC, read its data, compare it with the intensity of the same picture element in previous TV-fields which correspond to previous filterpositions and to update the feature vector if the new data shows a higher value than for previous filterpositions. After stepping through all relevant filterpositions (18 different angles with 36 different bandpass center frequencies each, the numbers are implementation dependent) the 256-element feature vector contains for each sample the filterposition which best matched the local properties of the input image. The timing diagram for a complete measuring sequence is shown in figure 4. The time needed for data aquisition and feature extraction depends mainly on the desired angle and frequency resolution of the feature vector. In the experimental setup used, the angle resolution was chosen to 10 degrees and the frequency resolution to a constant factor of 1.1, in order to achieve a constant

relative bandwidth. According to equation 1, the time for one measuring sequence is about 13 seconds.

$$T = 18\text{angles} \times 36\text{freq.} \times \frac{1 \text{ TV-field}}{\text{angle} \times \text{freq.}} \times \frac{20 \text{ msec}}{\text{TV-field}} = 13\text{sec} \quad (1)$$

The final classification, based on neighborhood comparison algorithms, takes less than one second of computing time, since the amount of data which has to be processed is very little (512 bytes =  $16 \times 16 \times 2$  bytes for frequency and angle).

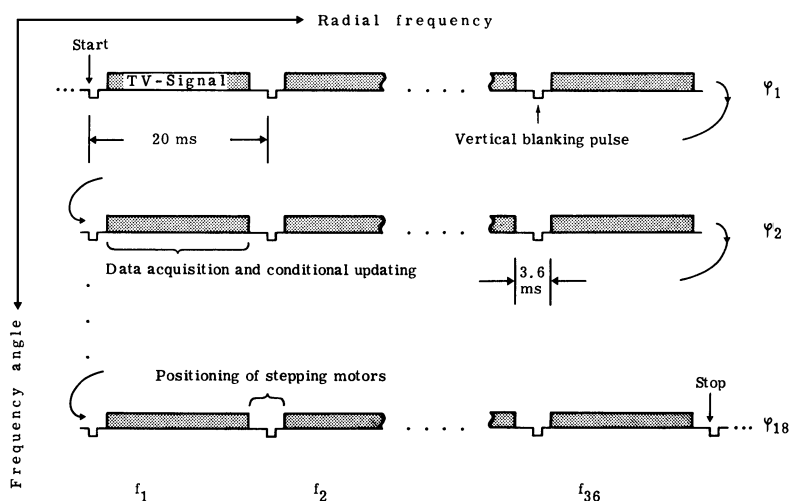


Fig. 4 Temporal succession of the microcomputer controlled data acquisition and filter positioning (real time)

### Experimental results

In order to get an impression of the preprocessors function, a testpattern (figure 5) consisting of 16 gratings, having four different frequencies, each in four different orientations, is used as an input image. The output is shown in figure 6 for the 16 different filterpositions which match the input pattern locally. Figure 7 shows a gradient representation printout of the digitally stored feature vector.

An actual interferogram of a metal plate is shown in figure 8. There are three welded joints on the other side of this plate. These areas shall be detected as a hypothetical task. Figure 9 shows the gradient field and figure 10 a simplified computer plot of the interferogram with inserted marks indicating the

automatically detected regions of interest.

# **Conclusion**

The presented concept of a hybrid interferogram evaluation system offers both high speed processing and good flexibility. The optical preprocessor allows data reduction factors of up to 2000, from about one megabyte of input data to 512 bytes of digitally stored local features and works on a great variety of input images without alterations.

The chosen features, local spatial frequency and angle, guarantee a minimal loss of relevant information. These features in conjunction with the flexibility of a digital computer allow easy computation of the final decision according to any given criterion. Furthermore the described technique is highly insensitive to artefacts commonly found in interferograms.

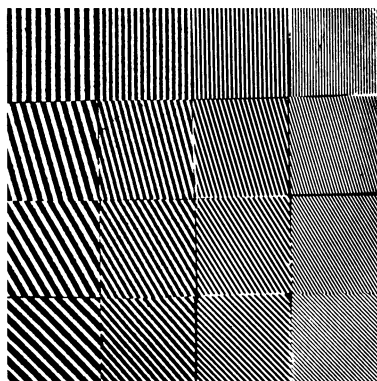


Fig. 5 Testpattern

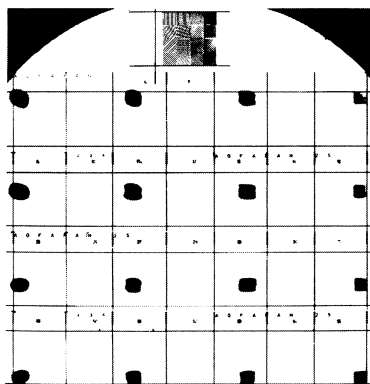


Fig. 6 Output of the preprocessor for 16 matched filter positions

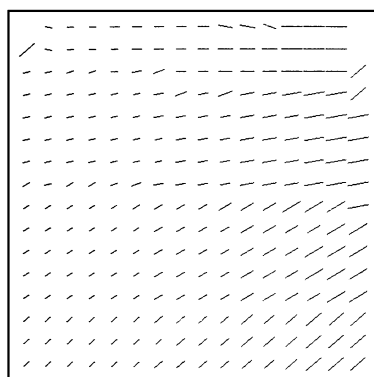


Fig. 7 Representation of the feature vector as a gradient field (short bar = low freq.)



Fig. 8 Interferogram of a metal plate showing irregularities on its surface

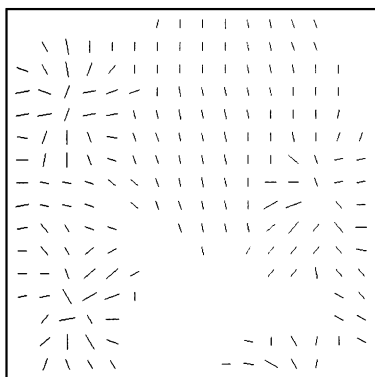


Fig. 9 Gradient field obtained from the interferogram (a lower frequency bound was set by the computer)



Fig. 10 Automatically detected irregularities

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