IMAGE PROCESSING FOR NONDESTRUCTIVE EVALUATION

M. H. Jacoby
Lockheed Missiles & Space Co.
Sunnyvale, California 94086

ABSTRACT

Digital image processing techniques can improve the interpretation and evaluation of radiographic and acoustic image data as well as the time domain waveforms produced by ultrasonic, eddy current, and acoustic emission — in two important ways. First, the image or waveform being evaluated can be enhanced to bring out detail not readily apparent to the observer. Second, the properly enhanced image or waveform can be evaluated automatically by computer. The size of defects can be measured, and accept/reject decisions made, without relying on the subjective interpretation of an inspector.

During the past ten years many new and innovative procedures have been developed for image enhancement and restoration. This presentation describes just one: the spatial filtering technique used to put acoustic and radiographic images in a mode suitable for automatic computer evaluation.

INTRODUCTION

The aim of image enhancement is to improve the visual appearance of images or to transform them into a representation suitable for computer analysis.

Review articles by Hunt and Hall give a comprehensive picture of the field and contain a total of almost 100 references and citations. More recently, Harrington and Doctor have extended these techniques to encompass ultrasonic, eddy-current, and acoustic emission testing technology. Pratt has written a textbook that gives mathematical and conceptual background as well as applications.

Pearson and his colleagues at Lockheed have described the use of enhancement methods as a starting point for automatic, computer-based image evaluation (see references 5 through 9).

In this presentation, spatial filtering and its applications to particular radiographic and acoustic images are shown. Other straightforward procedures — contrast stretching, trend removal and smoothing — will be demonstrated as part of the overall spatial filtering process.

SPATIAL FILTERING

Figure 1 reproduces a radiographic image of a glass-wrapped, rubber-insulated, cylindrical pressure vessel. The requirement is to process the image so that cuts in the insulation can be evaluated automatically by computer.

Fig. 1

The radiograph was scanned and digitized with a flying-spot scanner, and the result stored in memory as a two-dimensional 512 x 512 array of picture elements (pixels) with each 50 micron diameter pixel quantized to one of 2^9 = 512 gray shades. The contrast of the digitized image was stretched to accommodate the full nine-bit range, and global trends in image brightness were removed by curve fitting and subtraction. The result of these manipulations is shown in Fig. 2: a cut in the insulation is readily apparent.
Fig. 2 Contrast enhanced and gradient removed. The long vertical indication on the right hand side is the planned cut in the insulation. The much shorter indication on the left hand side was not planned. A bit to the left of the long indication is a small indication of a high-density inclusion either in the insulation or the glass.

Because of the way the pressure vessel is fabricated, cuts in the insulation can occur only in the vertical or horizontal direction on the radiograph. With this knowledge it is possible to develop a spatial filtering technique that will attenuate the image of the glass case (the cross-hatched lines). The filtered image will then contain only horizontal and vertical components and is thus presented to the computer in a mode highly suitable for automatic evaluation of cuts in the insulation.

In spatial filtering what is done is decompose the two-dimensional matrix of brightness values that represent the image into a linear combination of elementary functions. If Fourier analyses are used for the decomposition, the resulting elementary functions (which are sines and cosines) represent the spatial frequency of the image. The mathematical representation of this decomposition is given by the two-dimensional Fourier integral:

\[
  f(x, y) = \int \int F(u, v)e^{i2\pi(ux + vy)}dudv.
\]

The complex number \( F(u, v) \) is a weighting factor that must be applied to the elementary function \( e^{i2\pi(ux + vy)} \) in order to synthesize the original \( f(x, y) \).

Figure 3 is a representation of the magnitude of the spatial frequency components of the original radiograph. Since \( F(u,v) \) is a complex number there is also a spatial phase present. This phase is not shown in the diagram, but it is contained in the values stored in the computer memory.

Fig. 3 Spatial Frequency Spectrum

The two-dimensional Fourier transform of one particular spacing in the image plane is given by the magnitude of the impulse pair in the spatial frequency domain. To remove that particular spacing from the image plane, simply filter out the impulse pair and transform the filtered spectrum back into the image plane. It should be noted that no matter what section of a uniform scene is being considered, the magnitude of the spectrum is always the same and thus the filter function is always the same.

Figure 4 shows the filtered spectrum of the image. All the impulse pairs that make up the cross-hatch indications have been attenuated except one, the pair at \( u = 0, v = 0 \). This can be considered as the dc value of the image, and sets the background brightness level of the image.

Fig. 4 Filtered Spectrum
Figure 5 shows what happens when the filtered spectrum is transformed back into the image domain. The cross-hatch is indeed attenuated and the cuts in the insulation are quite clear.

Figure 6 is a smoothed version of Fig. 5 which somewhat reduces the indications of noise and permits efficient evaluation by computer.

Figure 7 is an acoustic image of a graphite-epoxy structure. The filtered image, Fig. 8, is in a mode more suitable for automatic evaluation of the defects.

It should be noted that the small vertical cut evident on the left hand side of Fig. 6 was not perceived at all on the original radiograph. A high density inclusion is also evident in the filtered image.
REFERENCES


