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Image processing applications in NDE

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Introduction

Nondestructive examination (NDE) can be defined as a technique or collection of techniques that permits one to determine some property of a material or object without damaging the object. There are a large number of such techniques and most of them use visual inspection in one form or another. They vary from holographic interferometry where displacements and stress are measured to the visual inspection of an object's surface to detect cracks after a penetrant has been applied. The use of image processing techniques on the images in the NDE is relatively new and can be divided into three general categories.

1. Classical image enhancement.
2. Densuration techniques.
3. Quantitative densitometry.

Rather than present a series of disjointed examples of each of the techniques, I will instead take one "product" produced by the Los Alamos Scientific Laboratory and attempt to show how image processing techniques are used to nondestructively and destructively [illegible] the product throughout its life cycle. I realize that I will stray outside the bounds of NDE. But I feel the understanding of how image processing can impact the manufacture and use of an object out weighs the liberties I will take. The "product" that will be followed is the microballoon target used in the laser fusion program. The laser target is a small (50-150μm) diameter glass sphere with typical wall thickness of [illegible] to [illegible] μm. The sphere may be used [illegible] or may be given a number of coatings of many kinds of materials.

Without going into the manufacturing process, suffice to say that the beads are [illegible] produced by the millions and the first nondestructive test is to separate the obviously bad beads (broken or incomplete) from the good ones. After this has been done, the [illegible] must be inspected for sphericity and wall thickness uniformity. This is accomplished by microradiography and visible light interferometry. The analysis of the microradiographic image is a perfect example of image processing of the quantitative densitometry category.

The microradiography of the glass, uncoated bead is performed on a specially designed low-energy x-ray machine[1]. The beads are mounted in a special jig and placed on a Kodak high resolution plate in a vacuum chamber that contains the x-ray source. The x-ray beam is made with an energy less than 2 keV and the resulting images are then inspected at a magnification of 500 to 1000X. Figure 1 illustrates some typical results. Figure 1a is the image of a defective bead and Fig. 1b is that of a mechanically good bead.

Fig. 1a Radiograph of defective bead

Fig. 1b Radiograph of good bead.

From this image, accurate measurements must be made of:

1. eccentricity of the spherical surfaces,
2. nonsphericity of either of the walls, and
3. lumps and/or thin spots.

Whitman et al[2] have developed techniques that produce quantitative estimates of these three parameters by scanning each radiographic image using a 2 μm x 2 μm aperature in a microdensitometer stepping 1 μm in a raster pattern.

The eccentricity is measured by calculating a number that represents the asymmetry of the radiographic image about some defined center. The asymmetry is empirically plotted against eccentricity using computer generated models. Using this technique, Whitman estimates that an eccentricity of 0.02 μm can be detected between the two surfaces of a 4[illegible] μm diam sphere. The accuracy of the method depends critically on the size and material of the bead, the energy of the x-ray beam and the wall thickness.

Detection of either nonsphericity or local inhomogeneities depends upon detecting deviations in optical density from an average for that particular defect type. Nonsphericity typically is detected by taking three identical radiographs but at three angular orientations. The optical density at the center of each radiograph is measured and any significant difference is cause for rejection. The criteria used for rejection is the statistical T test. Detecting and rejecting local inhomogeneities is similar to detecting nonsphericity but the complete image area is scanned and compared to a norm. Again the statistical T test is used for rejection. The precision of the method allows local defect and nonsphericity (measured as a difference in x-ray path length) to be measured as low as .03 μm.

Radiography is also performed on the coated beads but at a much higher energy ([illegible] 30 [illegible]). The purpose of this inspection is to measure the coat thickness. This is [illegible] plished by analyzing the microradiographs on a Model 177[illegible] analog image analyzer. A step wedge of the same material as the coating is radiographed with the bead. The optical density in the center of the bead is compared with the optical density of the step wedge and the double wall coating thickness is calculated. The color slicing feature of the analyzer is also used to estimate the uniformity of the wall thickness.

Interferometry is the primary means of inspecting the glass beads for wall thickness, wall conformity, and wall sphericity prior to coating. The beads are individually checked for these three conditions under a microscope. Figure 2 illustrates a typical bead.

Fig. 2. Interferogram of bead.

[illegible] much for the nondestructive applications of image processing. The last two applications I will discuss are more properly image generation techniques and are used to image the x-ray source formed when the sphere is imploded with a laser beam. Fenimore[3] et al have pioneered the use of coded aperature imaging for this application.

Basically the idea in coded aperature imaging is to form a large number of pinhole images of a luminous scene. The multitude of images is recorded on film and the original scene reconstructed using a microdensitometer to convert the optical density to digital form and then reconstructed using a balanced correlation method. The advantages of the coded aperature approach over a conventional pinhole is the increased signal-to-noise ratio at the same angular resolution. Figure 3 illustrates schematically the approach taken in this type of imaging. An additional advantage of using the coded aperature is the availability of the depth information that in principle is available to the experimenter. Reference 4 describes the process in much more detail.

Fig. 3. Schematic of URA processing.

Fig. 4. Typical uniformly redundant array.

Figure 4 illustrates a typical uniformly redundant aperature (URA) while Fig. 5 compares the image formed by a 25 μm pinhole and a URA image of an imploding bead. Note how favorably the two images compare. Incidently, the URA image received approximately 10[illegible] more photons/μm² in the brightest spot than the pinhole image.

Fig. 5. Pinhole image URA image.

The last imaging technique I will discuss is an adaptation of computerized tomography. Minerbo[6][6][7] et al have developed an algorithm that reconstructs a cross section of the x-ray bright target using pinhole (or reconstructed coded aperature) data.

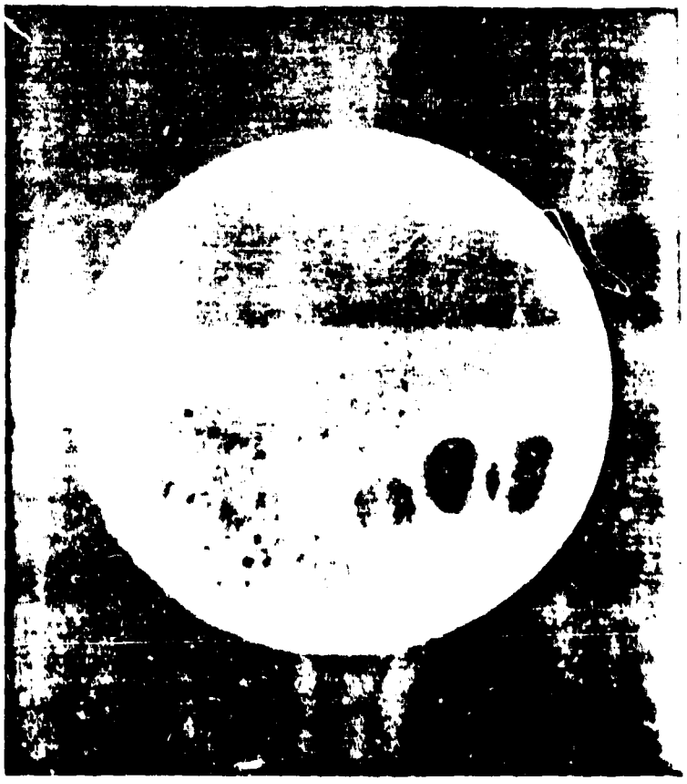
The computer code is based on the maximum entropy algorithm using four independent views of the source. With this small number of views, the problem is known to be indeterminant, i.e., there is an infinite number of possible source distributions that agree with the measured projection data. The maximum entropy algorithm selects as the best source distribution that one that is the most "probable" in the sense that it has the least information content (maximum entropy) of all the possible distributions.

The data is collected with four pinhole cameras arrayed at 90° intervals around the imploding sphere. The pinholes are 20 μm diam and are covered with 12 μm beryllium foil to block out all photons with an energy below 1 kV. The geometry was such as to give a magnification ratio of 9 and an object resolution of 11 μm.

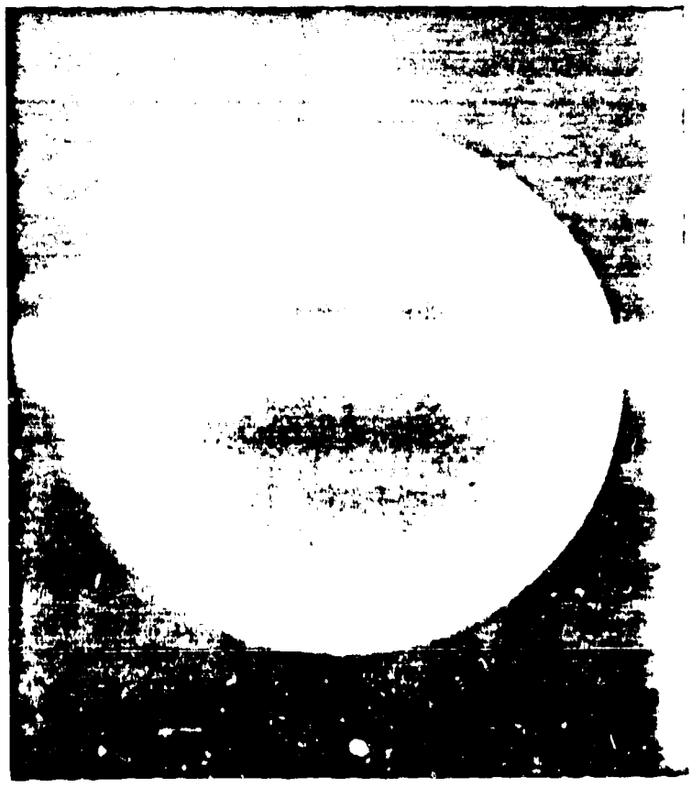
These examples illustrate how image processing techniques are applied to just one scientific program at the Los Alamos Scientific Laboratory. They are used not only during the manufacturing phase when nondestructive testing methods are applied but also during destructive testing of the beads. As image processing techniques become better known and developed, they are being applied more and more to generate more quantitative nondestructive testing results.

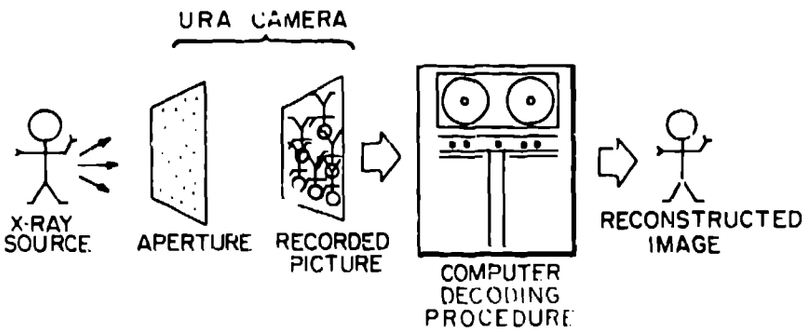
References

1. M. A. Winkler, "Microradiographic Inspection of Laser Fusion Targets," presented at the meeting of the American Society for Nondestructive Testing, Denver, 1978.
2. R. L. Whitman, R. H. Day, R. P. Kruger, and D. M. Stupin, Appl. Opt. 18, 1266 (1979).
3. E. E. Fenimore and T. M. Cannon, Appl. Opt. 17, 337 (1978).
4. E. E. Fenimore, T. M. Cannon, D. P. Van Hulsteyn, and P. Lee, Appl. Opt. 18, [illegible] (1979).
5. G. N. Minerbo, "MENT: A Maximum Entropy Algorithm for Reconstructing a Source from Projection data," to be published in Comput. Graph. Image Proc.
6. G. N. Minerbo and J. G. Sanderson, "Reconstruction of a Source from a Few Coarse Projections," Los Alamos Scientific Laboratory Report, LA-6747-MS, March 1977.



1a

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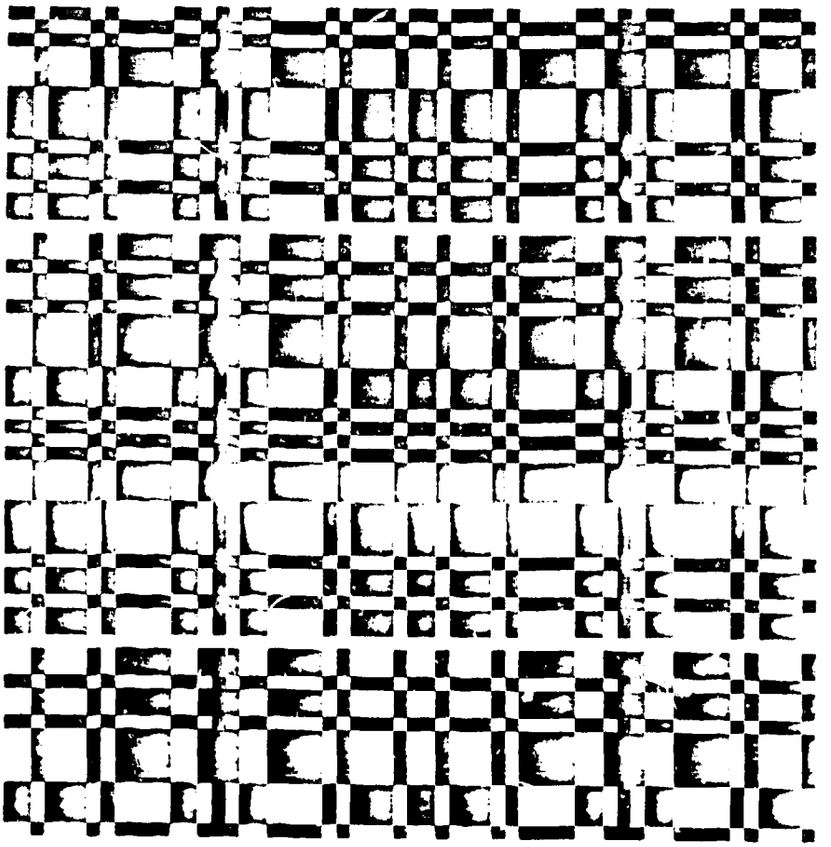
Fig 3