Zoological Studies 34, Supplement I (1995)

Zoological Studies

Can X-ray Photometry Be Applied to 3-D images?

Sterling P. Newberry
11 S., Westcott Road Schenectady, NY 12306, USA

STATEMENTS OF PROBLEMS

X-Ray Microscopes which do not use the brilliance of the synchrotron are deficient by comparison to those which do use synchrotron x-rays on two counts. They have far less intensity in the very soft region and they cannot have continuously variable, monoenergetic illumination which is so helpful in chemical identification. However, they have two important advantages over synchrotron illuminated microscopes. They are small enough to be fitted into an ordinary laboratory space and they are far less expensive. Since these smaller microscopes produce very useful images for a large range of subjects, and can be made available to a wider user group, it behooves us to look for ways to enhance their performance in these two areas. In this paper we shall narrow the scope of the paper to the Shadow Projection type of microscope, which is still the most attractive of the laboratory source illuminated instruments.

BACKGROUND EXPERIENCE

Our experience has shown that thickness sensitivity has not been a problem due to the use of 5 kV and higher beam energy. Thin organic films, smoke from oil fires, charcoal, and plastic foams are easily imaged. Difficulty arises in getting image contrast in very uniform mixtures of organic materials. Computer enhancement has been of considerable help here. What is most troublesome is the inability to distinguish between materials of very nearly the same atomic weight. Past work on this latter problem has concentrated on the use of two line sources on either side of a prominent absorption edge to identify a component. While this has had some application in micro-radiography where one may easily select line radiation from white radiation by Bragg reflections it is less convenient for projection images. It also suffers from lack of generality.

SUGGESTION TO EMPLOY X-RAY PHOTOMETRY

Another attractive approach would be to use x-ray photometry since the absorption characteristics of all the elements are cataloged and the absorption of compounds can be calculated or measured in pure samples. Photometry has long been used for samples such as thin sections in which the material is the same, in a given area, through out the thickness of the sample. It has not been used with thicker samples if the material varied in the Z direction. With tomography, the absorption of individual voxels can be measured and thus in principle photometry can be applied to determine the composition of small regions even if the sample is not homogenous in the Z direction. Using the same principles, can the voxel absorption be determined in the much more convenient 3-D display?

In visual examination of 3-D displays one can easily see a small region of different density even though it lies in a plane between regions of yet other densities. We generally record 3-D images with photographic material which complicates photometry but does not preclude it. With CCD or other electronic image detectors now available the photographic material need not be used. Areal mapping techniques can identify planes of constant Z value and thus identify conjugate voxels in the two stereo views. The basic question is whether two views are adequate for calculating the x-ray density of a voxel. With the larger number of views in tomography it is reasonable to assume that the path overall density variations average out. Visually the 3-D views appear to do the same. The question remains, however, that the human brain, which is such an efficient tomographic computer, may be deceiving us with respect to the absolute value of the voxels. As we know the human visual system is a sensitive ratio detector but tends to ignore the back ground level. I shall argue that for 3-D views in which the small details have good contrast, a measurement of the photons in an x-ray pencil corresponding to one voxel's back projected area, compared with the average of back projected voxels which surround the border of the small detail, will give the true absorption of that small detail. Furthermore, that the quality of a given small detail for analysis can be selected automatically so that only the better voxels are included in an analysis.

SUGGESTION FOR CHEMICAL CONTRAST ENHANCEMENT

There is still the question of whether we can hope to distinguish chemically different materials which appear to have equal absorbing power in an image. That is can we find a general way to accomplish what the two exposures which straddle the critical absorption edge have done in a few favored cases. For this final problem I shall propose a method which can be used in conjunction with the determination of voxel density by 3-D analysis. The idea is to compare three sets of pictures taken by three different narrow band exposures. Here we can expect that since the absorption coefficients vary so rapidly with wave length, that in those cases where the compounds to be expected are known, one can distinguish between closely related compounds. As a matter of experience we have found that the likely components in a sample are generally known. An unexpected component becomes obvious by comparison, and once identified in space, can be studied by other analytical methods.

1. The author is grateful to Professor P.C. Cheng for useful discussions concerning these problems.