IMAGE ANALYSIS BY ON-LINE MINICOMPUTER FOR IMPROVED CAMERA QUALITY CONTROL

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The necessity for reasonable uniformity in the field response of a gamma camera is widely accepted (*1–3*). What constitutes "reasonable" uniformity and how to evaluate this parameter is far less certain (*4–6*). The usual method of visually inspecting an image of a flooded field for visible nonuniformity lacks sensitivity and precision. The use of minicomputers interfaced to cameras has been growing in popularity. As problems of comparison lend themselves well to computer analysis, it appeared that this would be a useful method of attacking the problem of quantitatively evaluating camera field uniformity.

METHODS

Programming and computation was done on a Digital Equipment Corp. PDP-8/L computer with 4K of core which was incorporated into a Nuclear Data Corp. 50/50 Med System (*7*). All studies were done with this equipment package interfaced to a Nuclear-Chicago Pho/Gamma III.

Flooded fields were obtained using an extended sheet source consisting of a watertight Plexiglas box measuring 15 × 15 × 2 in. filled with dilute ^{99m}Tc-pertechnetate solution. The amount of technetium was adjusted to give a counting rate of less than 100,000 cpm to approximate clinical counting rates.

Flooded images were obtained through a low-energy, parallel-hole collimator to simulate clinical imaging conditions and to minimize the edge packing effect seen with flooded fields done with a bare crystal.

Field uniformity evaluation program. As the field flood image is acquired, it is digitized in a 64 × 64 matrix and stored in one field of the 50/50 memory. The equipment is adjusted so that the circular image is centered at memory address x = 32, y = 32 and just reaches the borders of the matrix, i.e., image radius equals 32 channels.

The "Camera Check" program examines the digitized image twice. On the first pass a "per channel" mean is calculated. Only those channels which actually represent the image are included in this calculation. This is accomplished by considering only those points which lie within a designated radius of the image center. We have usually used a radius of 30 channels as this eliminates the small edge packing effect seen even with a collimator. The per channel mean thus equals

$$\frac{\text{Total counts in image of radius R}}{\text{Total points within image of radius R}}.$$

The second pass checks each image channel's actual value against limits based upon the calculated mean. These comparison limits allow for normal instrument tolerances and statistical fluctuation as follows:

$$\text{acceptable limits} = \bar{x} \pm (\%\bar{x} + 2\sqrt{\bar{x}}),$$

where

$\bar{x}$ = calculated per channel mean from first pass,
$\%\bar{x}$ = acceptable variation from perfect uniformity,
$2\sqrt{\bar{x}}$ = two-standard deviation allowance for counting statistics.

Image points which exceed these limits are mapped in a second memory field. Points above the maximum acceptable are placed in a "high" location and those below in a "low" location (see Fig. 1B–D). Finally, a printout is produced listing the observed per channel mean, the total number of channels considered in the calculation, the total number of channels which exceed prescribed limits, and the percent of channels which are acceptable.

A second part of the program allows the operator

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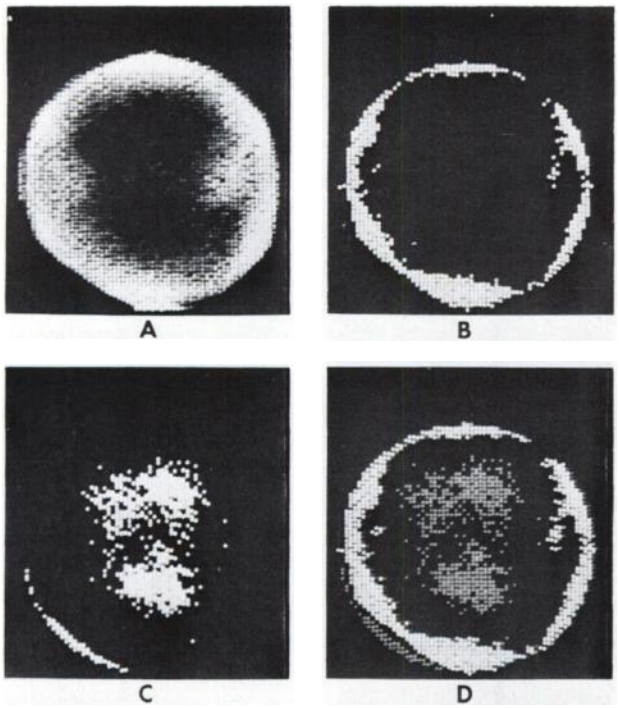

FIG. 1. A, flooded field image from badly-tuned camera. Image is in digital form. B, high map, showing locations value of which exceeds upper limit. C, low map, showing locations below lower limit. D, composite high, low map with high values in white and low values in gray. Limits used are $\%\bar{x} = 15\%$.

to flag a region of interest and determine the per channel mean of the points within that area. This area mean is then compared with the overall mean. This is helpful when one area of the image appears to be biasing the first part of the program. A printout is produced listing the per channel mean of the flagged areas and the flagged-to-total ratio of means.

DISCUSSION

Ideally, determination of field uniformity should be a routine part of camera quality control procedures. The usual way of doing this is to examine a photographic image visually for hot and cold spots. This method has the disadvantage that variations of as much as ±20% in uniformity may not be visible. This is particularly true if Polaroid film is used. It can, of course, be maintained that a response variation which is undetectable on film would have no effect on clinical images. However, such large variations, if undetected, can introduce serious errors if quantification of the data is attempted (*4*) and seriously reduce the sensitivity of the technique. A good quality control procedure should detect developing problems before they interfere with clinical studies.

Flooded field images may be examined quantitatively by examining serial profiles of a digitized field flood image and determining the absolute height of the peaks and valleys. This is considerably more sensitive than the photographic method but has the disadvantage of being very time-consuming and tedious.

Our computerized technique has several advantages. It is quantitative and makes due allowance for both equipment design tolerances and statistical variations. It has good sensitivity and the method of display calls the observer's attention to areas of concern much more clearly than other methods. Moreover, the sensitivity can be easily altered by changing the limits of acceptability. Since the procedure is completely automated, it makes little demand on the technologist's or physician's time. The map of high and low areas immediately directs attention to the proper photomultiplier tubes which need attention. Local defects which cannot be tuned out point by inference to a defect in the crystal so that this type of problem can also be localized. Allowance must be made for the changes in field uniformity seen with increasing counting rates. Field flood data should be acquired at a rate approximating that seen in clinical studies if meaningful results are to be obtained.

The major disadvantage to this technique is the need for interfacing to a computer, thus limiting its general applicability. A secondary disadvantage lies in the fact that new programming would be necessary for each type of computer system. This is a minor problem since the programming is quite simple and should be readily adaptable to any computer-based nuclear medical data-handling equipment.

SUMMARY

A method of evaluating camera field uniformity by the analysis of a flooded field image by an on-line minicomputer incorporated in a commercially available digital data processing and storage system is described. The technique produces a map of those areas which vary by more than specified amounts from the mean level. Points which are above and below the mean are plotted separately. Statistical variability is also taken into account. A printout of the mean level and the percentage of the field which deviates by more than the chosen limits from the mean is also provided.

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