AUTOMATIC MEASUREMENT OF HAILPAD IMPRESSIONS

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ABSTRACT

This paper describes an automatic method for finding the number and size of hail indentations in hailpads. The approach taken was to scan the pads with a TV camera, and digitize the output. The digitized image is then thresholded to produce a binary image. From the binary image, the boundaries and size of the closed regions are obtained, and the distribution computed. The results obtained and the problems encountered are illustrated.

MESURE AUTOMATIQUE DES IMPRESSIONS FAITES PAR LA GRÊLE SUR UNE SURFACE TÉMOIN

ABRÉGÉ

Le présent mémoire décrit une méthode automatique d'indication du nombre et de la taille des impressions faites par la grêle sur une surface. La technique consiste à analyser cette surface à l'aide d'une caméra de télévision et à traduire la sortie en numérique. L'image numérique est transformée en image binaire. A partir de cette image, les contours et les dimensions des régions closes sont obtenus et la répartition informatisée. Les auteurs donnent les résultats obtenus et traitent des problèmes qu'il leur a fallu résoudre.

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INTRODUCTION

The purpose of this project is to find the number and size of indentations in hailpads. A hailpad is a 1'x1'x1" piece of styrofoam covered on one face and four sides by a piece of aluminum foil. Hailstones falling onto the pad produce indentations in the aluminum foil and the styrofoam as shown in Fig. 1. If the number of indentations and their sizes are known, the amount of hail on that square foot can be calculated [1]. As a result, hailpads can be used as a means to record the impact energy of hailstorms.

The difficulty, however, is that it is not easy to measure the sizes of the indentations because the sizes of hailstones are usually small (< 2 cm in diameter) and the number is usually high (> 100). To measure the size manually using a ruler is very time-consuming and often inaccurate due to the problem of keeping track, and acute boredom. In addition, large numbers of the pads (> 1,000) are collected each year for analysis. Attempts have been made [1], with some success, to sample the 1 sq. ft. area with a smaller subregion to reduce the tedium. It is then possible to question the need of a 1'x1' pad if only a smaller area is actually used. In addition, since the 1 sq. ft. area is merely a sample itself, what kind of errors are produced when a further sample is taken. This leads to the conclusion that there is a need for a method, which is fast, inexpensive and produces accurate consistent results. This paper describes an attempt to produce just such a method using picture processing.

EQUIPMENT

In order to solve the given problem, a digital picture processing system, DIPPS [2], was available. This system uses a standard TV camera for picture input, a PDP-9 computer for picture manipulation and storage, and a 611 storage CRT for output. In addition, a considerable amount of software was available under a picture operating system, POPS, to make the problem of trying many variations possible, and easy.

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METHOD

In order to better understand the complete problem it can be divided into the following steps:

1. Quantization of the hailpad image.
2. Transformation or other manipulation of the obtained matrix into a binary image where the pixels contained in regions representing the indentation are transformed into 1 and all other pixels are 0.
3. From the binary image obtained in 2, determine the indentation boundaries, the size of the indentation and then the statistics for the complete pad.

QUANTIZATION

Due to the reflective and monochromatic nature of aluminum foil, it is difficult to obtain a good binary image as seen in Fig. 2. The distribution of grey levels concentrates towards the maximum grey level (63), as shown in Fig. 3. Consequently, the contrast of the picture is greatly reduced. It is essential to obtain a good digital picture of the hailpad because any information lost in the quantization process is not available in the subsequent steps of the entire process. Two main factors affecting the quality of a picture are the resolution of the camera and the illumination of the hailpad. In order to determine the effect of illumination, a number of variations were attempted, and close-up pictures were made of a single indentation, as shown in Fig. 4.

In these pictures the following lighting arrangements were used:

1. P(1,1): 1 light, 10^{o} to the left.
2. P(1,2): 1 light, 10^{o} to the right.
3. P(1,3): Both of 1 and 2 above.
4. P(2,1): 1 light, 30^{o} to the left.
5. P(2,2): 1 light, 30^{o} to the right.
6. P(2,3): Both of 4 and 5 above.
7. P(3,1): 2 lights, 45^{o} on both sides.
8. P(3,2): 2 lights, 60^{o} above and below.
9. P(3,3): Same as 8 with additional fluorescent lights from the ceiling.

The method producing the most consistent results over the whole pad is to shine diffused light onto the hailpad such that the incident light is approximately perpendicular to the hailpad.

The light source should be as far away from the hailpad as possible. The advantages are, that the light incident on the hailpad is almost perpendicular to it, and since the intensity is not too high, a wide grey level distribution may result. In general, no matter what the light setting was, adverse effects were produced on the digital image. When the incident light is perpendicular to the hailpad surface, indentations on the hailpad appear like dark rings instead of dark circles. This is due to the flattened bottom of the indentations on the aluminum foil. When the incident light is at an angle to the hailpad, the shape of the indentations are changed, usually stretched to an oval shape, due to the shadows produced.

TRANSFORMATION

The better the contrast of a grey level hailpad picture, the easier it is to distinguish indentations from the background. Unfortunately contrast in hailpad pictures are usually poor because of the reflective aluminum cover. Therefore, it may be desirable to improve the contrast before tracing the indentations. In addition, there is a spatial variation in the contrast of the picture. If this picture were converted into a binary picture with indented areas represented by 1 and the background represented by 0, this conversion will require a complicated mapping function because of the non-homogeneous grey level difference. However, a binary mapping is desirable because it enables easy tracing and measuring of indented areas. One simple method which may not be accurate enough as far as the preservation of information is concerned, is to determine some threshold value. All grey levels greater than or equal to this threshold are mapped to 0 while the remainder are mapped to 1. This transforms a grey level picture with many levels into a binary picture with indentations represented by 1's and the background by 0's. The threshold value can often be determined by trial and error from the distribution of the overall picture matrix. The problem is to find some critical value which when applied to all pictures produces an appropriate binary picture without much loss in information. Experiments show that any threshold value between 30 and 32 (octal) is reasonable.

The problems encountered during attempts to convert hailpad images into binary images lead to one additional experiment. A hailpad that was indented by steel balls, and therefore well calibrated, had the aluminum foil removed, and was inked with a roller. Unfortunately, the inking process was not done too well and several black splotches appear on the pad where the ink was applied directly to the pad (see Fig. 5). Other than the one minor incident, the experiment was successful, since the background is essentially black and the indentations are essentially blue (the color of the styrofoam) and show up as white in the digitized image (see Fig. 6). As shown in Fig. 7, this permits a simple transform which yields a much better binary image. Unfortunately, this approach was not attempted on an actual hailpad.

After transformation, the resulting picture matrix will be composed of regions of 1's corresponding to the indentations and the rest of the elements 0. The next problem is to locate each indentation and find its diameter.

BOUNDARY DETERMINATION

This algorithm assumes the following:

1. All elements within a region must be 1.
2. Each region must be closed.
3. All regions are convex.

Each region is scanned column by column from left to right. After scanning, a rectangle can be formed from the 4 pointers containing the row or column number of the outermost points of a region. From this rectangle, the size of an indentation can be determined. Each rectangle is represented in memory by 2 ordered pairs (L, R). L contains the coordinates of the top-left point of the rectangle and R contains the coordinates of the bottom-right point. The coordinates are expressed in terms of row and column numbers of the picture matrix. When the complete matrix is scanned, an array of these ordered pairs is formed. From this array, the minimum width of each rectangle can be determined. Accordingly this width corresponds to the minimum diameter of a unique indentation on the hailpad. The result is not always reliable because the assumptions stated are not always satisfied. For example, not all regions are closed, and often indentations overlap or touch one another.

As mentioned previously, values corresponding to minimum diameters of indentations can be calculated from the array of coordinate points resulting from the edge tracing program. Due to the results produced by irregular regions, it is felt that the elimination of rectangles that are contained in other rectangles provide better results. Elimination of overlapping rectangles and replacing them by an enclosing rectangle was considered, but not carried out since these results are usually valid.

After this array is processed, and unwanted data eliminated, a frequency table of indentation diameters is printed. These diameters are expressed in terms of the number of rows or columns in the picture matrix. They can be converted to real size by multiplying the diameters by a conversion factor.

CONCLUSIONS

The results of applying the algorithm is given in Figs. 8 and 9. The conclusions drawn from these pictures are clear. It is difficult, using the approach tried here, to digitize and automatically count the indentations in the aluminum foil of a hailpad. The approach of inking with a roller the styrofoam pad itself is more promising; however, further study is necessary before an unqualified statement can be made.

ACKNOWLEDGEMENT

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2. W. A. Davis, et. al., "A System for Processing Digital Pictures". Proc. 3rd Man-Computer Communications Seminar, Ottawa, May 1973.

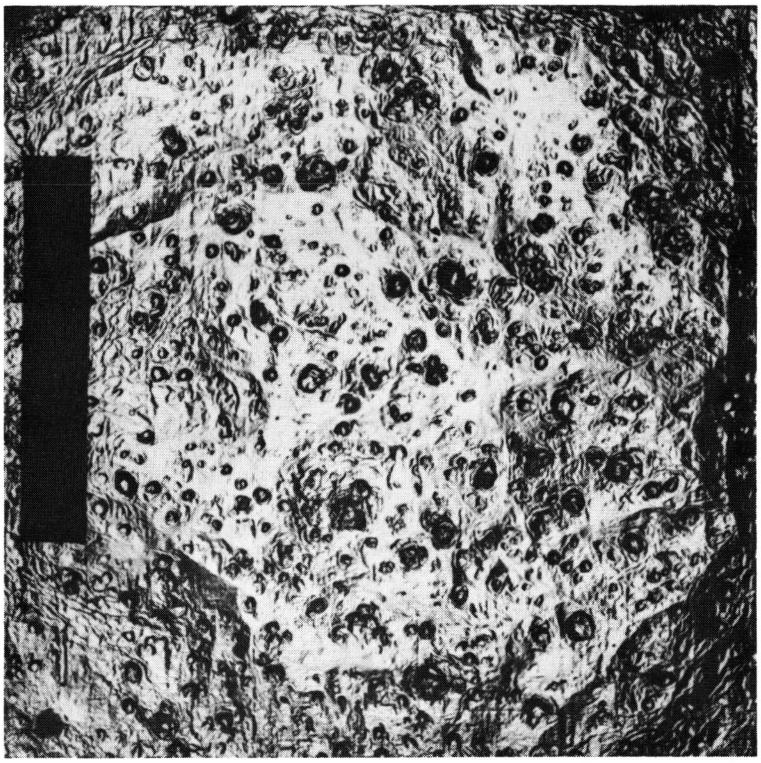

Fig. 1. Hailpad

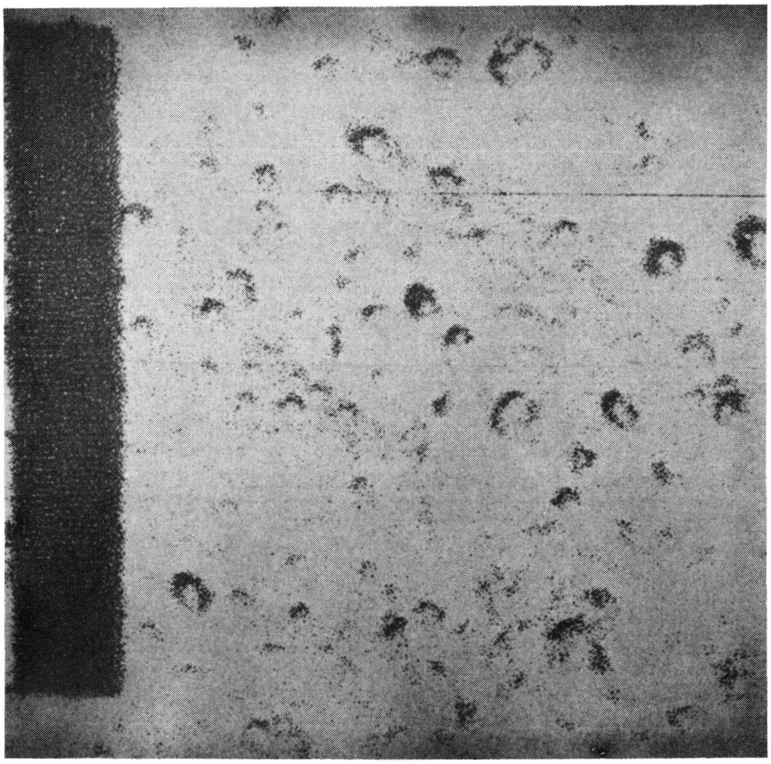

Fig. 2. Digitized Hailpad Image

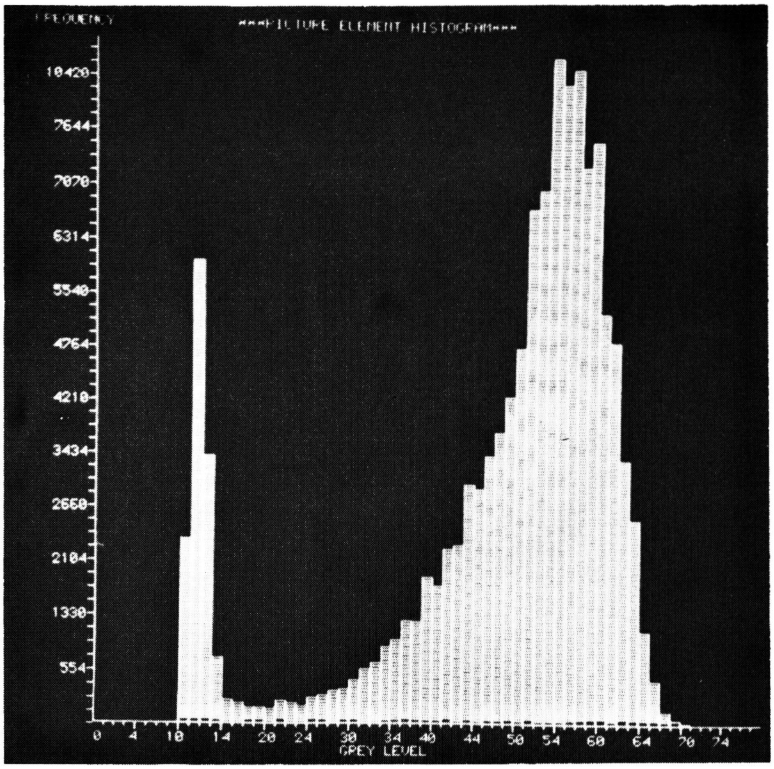

Fig. 3. Histogram of Fig. 2

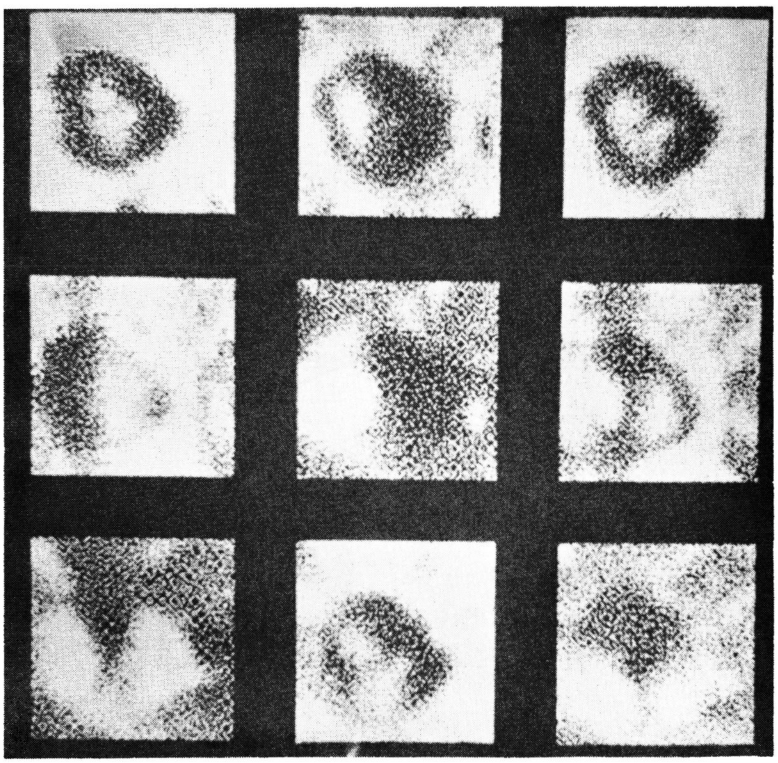

Fig. 4. 9 Illuminations of One Indentation

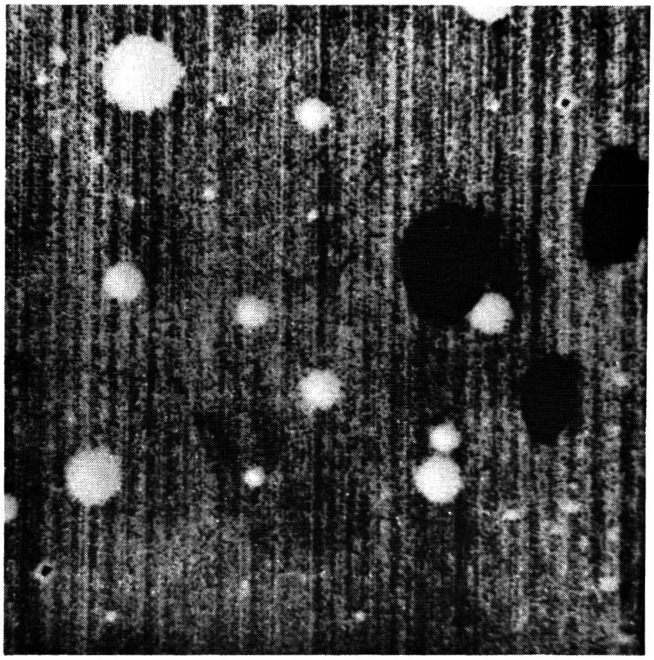

Fig. 5. Inked Pad with Aluminum Foil Removed

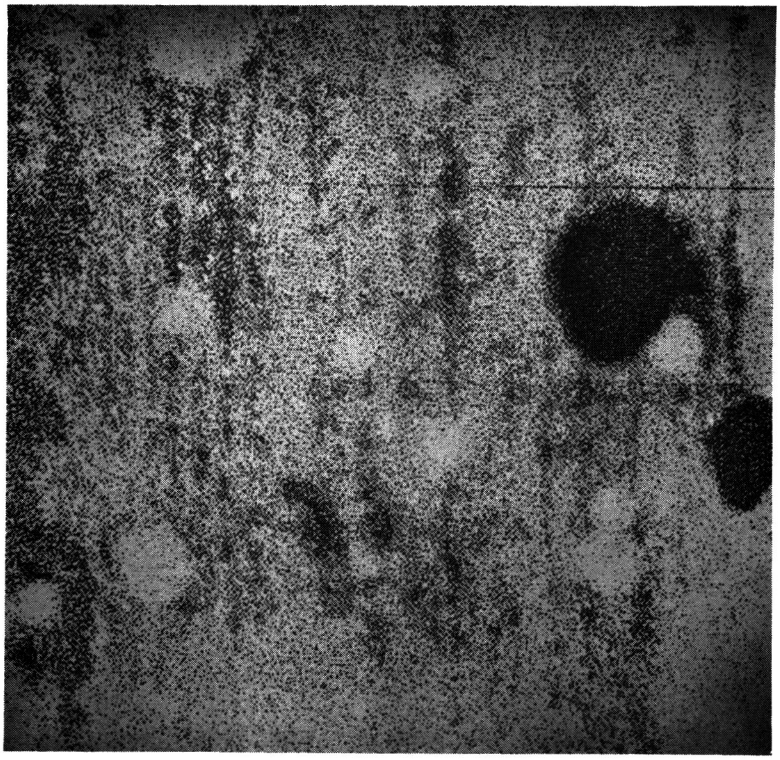

Fig. 6. Digitized Version of Fig. 5

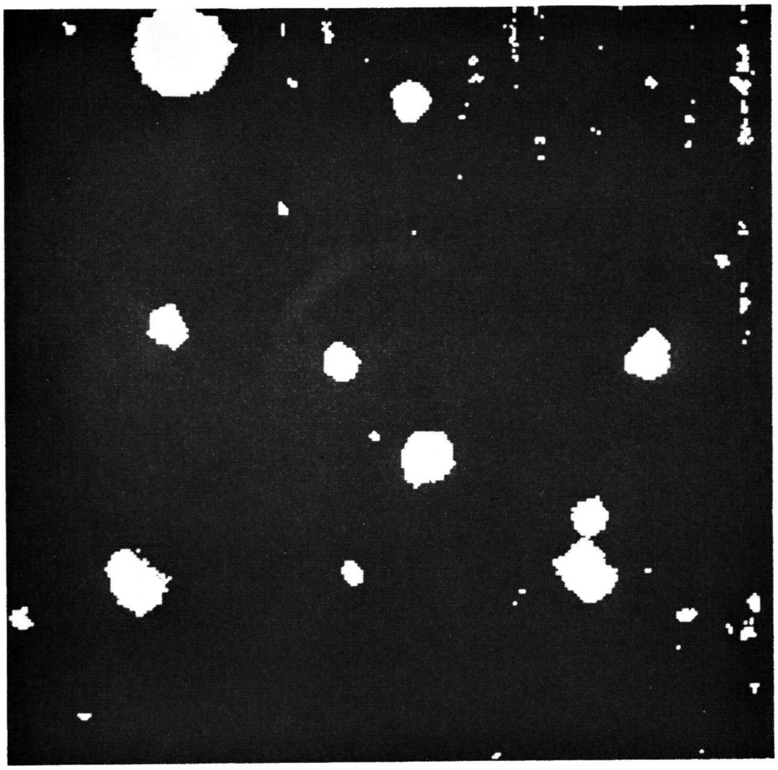

Fig. 7. Transform of Fig. 6

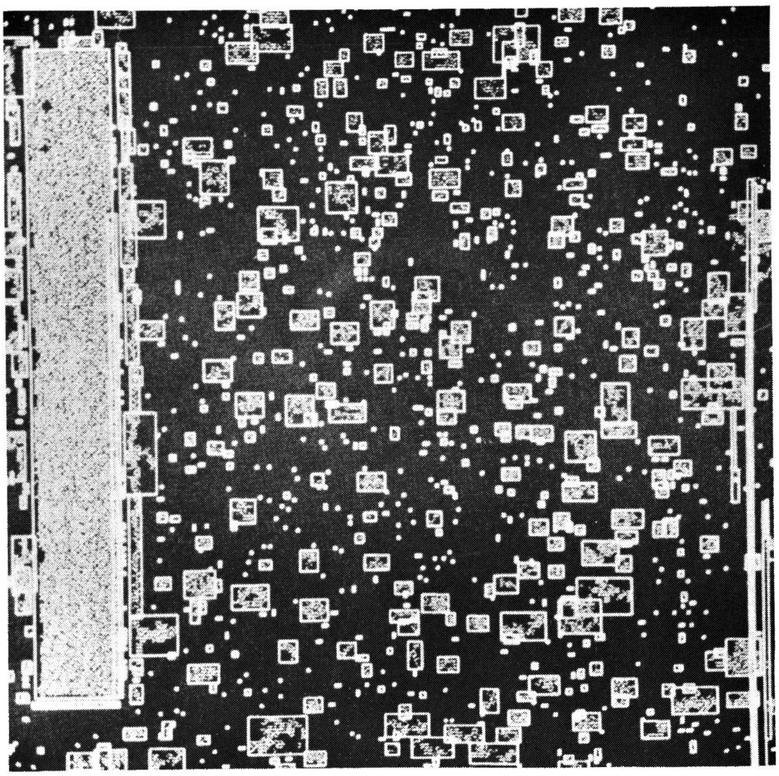

Fig. 8. Boundaries of Indentations from Fig. 2

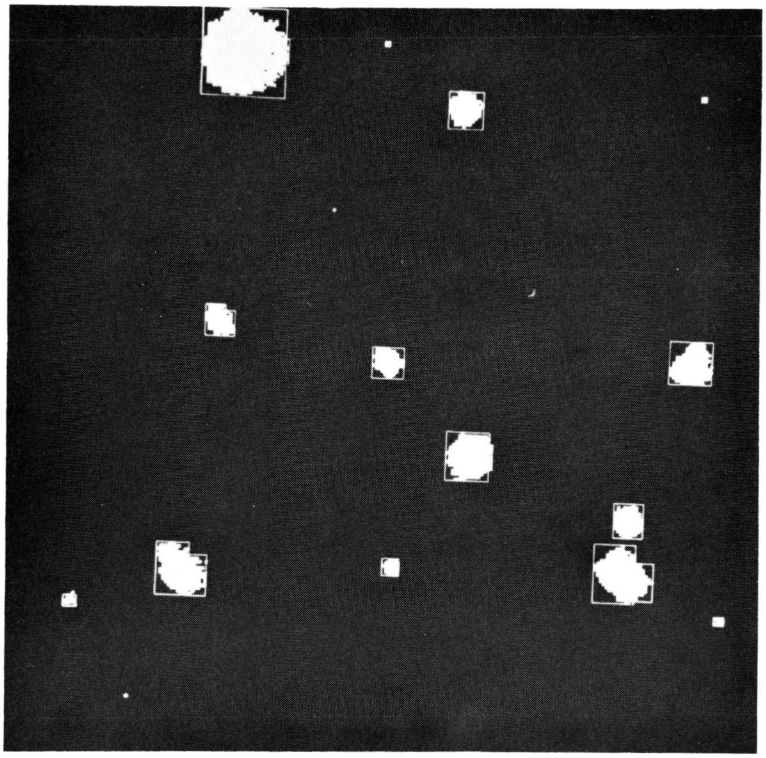

Fig. 9. Boundaries of Indentations from Fig. 6