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PREPROCESSING OF PHERMEX FLASH RADIOGRAPHIC IMAGES

by

John E. Brolley

ABSTRACT

Preparation of PHERMEX images for optimal viewing and/or interactive mensuration is considered. Physiological factors are discussed and then remapping of image density and redistribution of spectral power by sequency analysis are demonstrated.

I. INTRODUCTION

Although the highly trained viewer may often discern features in an image that escape the untutored eye, it is possible to further improve the acuity of the specialist by preprocessing the image. There may be information in the gray level structure of an image which is extractable but which is below the threshold of the human visual system.

The extraction of information is affected by interactions in two broad categories. These will not be sharply defined and may be expected to have overlapping areas. In the first category may be deposited factors such as vigilance and task motivation, i.e., mental attitudes. These are factors which an organization should have cognizance of and seek to optimize. Thus, for example, it is well known that vigilance decreases logarithmically with time, and as pertains to the present problem, it degrades by a factor of two in one-half hour. This report will be concerned primarily with the second category which includes approximately quantitative performance estimates having an apparently physiological basis.

The simple discussion to follow is merely intended as a prologue to an introduction* and will use as a didactic aid the Swiss cheese problem. Couched in mundane terms the problem is: given a Swiss cheese in dim light, can one discern all the holes and cracks and essay their mensuration?

Some pertinent attributes of human vision will now be considered.

Consider initially the smallest holes and assume they are circular, then Ricco's law states that

$$\varepsilon\alpha^2 = \text{constant} ,$$

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*The discussion of Overington is followed. A valuable and comprehensive set of references may be found in his book.[1] Ruddock[2] has written a slightly more recent review.

where ε is the liminal contrast (50% probability of detection) and α is the angular diameter of the hole. Since ε is the ratio of the object luminance to the surrounding luminance, it has no units. Thus, as the object grows larger it can be discerned at a lower contrast level. After approximately 60 milliradians there is no further gain. Another related effect is the influence of field luminance. As the general field luminance diminishes, the threshold contrast level rises. This property is depicted in Fig. 1. The cusp in Fig. 1 is attributed to a change from rod to cone vision. The results of Fig. 1 apply only after the eye has adapted itself to the particular level of power input. If the object is rectangular, the threshold of detection is also influenced by the aspect ratio. The threshold of detection is also influenced by the sharpness of the boundaries. This effect is most marked for small targets. Some appreciation of this phenomenon may be gleaned from Fig. 2. The effects of blur on detection thresholds are a function of time and estimate size. As the viewing time increases, the threshold also increases. Color also influences the threshold in various ways. Of particular interest is the variation of the chromaticity threshold with wavelength. This effect is displayed in Fig. 3. Two spectral regions appear to afford the lowest thresholds. It may be noted that there is a difference between positive-negative and negative-positive thresholds. By positive-negative is meant that the object of stimulus is radiating more energy per unit area than the surrounding field. Negative-positive is the opposite relation. The human eye can detect lower negative-positive thresholds than positive-negative. Lastly, orientation effects occur. Thus, vertical lines have the lowest threshold. Horizontal lines have the next lowest threshold, whereas lines at 45° have the highest threshold.

II. DIADS IMPLEMENTATION

The Digital Image and Signal Processing Group has assembled the DIADS (Digital Image Analysis and Display System) facility. It is a powerful tool for manipulating and displaying images in either black and white or color. DIADS is comprised of the following principal components:

5000 series COMTAL Digital Image Display with three graphic CRT (cathode ray tube) monitors
8000 series COMTAL Image Processing and Display
Both have large CRTs for black and white and color display.

PDP 11/40 CPU with
- 88k words of core memory
- 5M bytes of RK05 disk storage
- 256k bytes of RF disk storage
- VT05 alphanumeric terminal
- Dec-writer terminal
- 7-track magnetic tape drive
- Line printer
- Dec tape

UNIX operating system
C-language compiler

The physical disposition of DIADS is shown in Figs. 4 and 5. Adjunct to DIADS is a Photometric Data Systems (PDS) film scanner which can scan film areas up to 0.3 by 0.4 m. The PDS laboratory is shown in Figs. 6 and 7. The PDS output is digitized and put on tape for subsequent manipulation in the CCF (Central Computer Facility) and DIADS. Image processing is facilitated by using the computer library LADIES (Los Alamos Digital Image Enhancement System) which was assembled and is maintained by group M-8.

The first phase of preprocessing of the PHERMEX flash radiographic images is to convert them to digital matrices. If the image were to be produced by a CCD (Charged Coupled Device) matrix, it would already be in digital matrix form. If the image were on film, it would have to be converted to a digital matrix by scanning it with the PDS.

The simplest operation that might be indicated is a reversal of the image presented by DIADS to capitalize on the negative-positive boundary situation in an area of interest on the image. An option is available in the LADIES programs to invert the picture matrix.

It is clear from the introduction that there exists the possibility of enhancing the threshold of boundaries and their general visibility to the eye by increasing the power differential across the boundary. This can be done in a variety of ways. Two will be considered here. Equivalent to increasing the power differential is increasing the density differential. As imaging moves increasingly towards CCD matrices, the first statement will be more appropriate. The present hardware and software systems are structured to accommodate film densities up to 5. The LADIES library provides the ability to monotonically linearly remap the film density. If the maximum density in the picture matrix is $\rho < 5$, then a linear mapping as shown in Fig. 8 can be obtained for the matrix. The new mapping can then be displayed by DIADS on a CRT.

A more sophisticated version of the density-stretching operation is to employ a piecewise linearly mapped density. This mapping is depicted in Fig. 9. The effect of this mapping is to transform a narrow spread in density to a wider spread. This has been incorporated in DIADS with two options. The first option permits a sequence of images to be automatically presented, much in the style of a motion picture. In this sequence the line ab shifts to the right, maintaining its slope and length. In the second option, ab can be manually displaced to the right to facilitate photography and perusal of a particular mapping. Control of the shape of the curve is provided. Both options are also provided for density slicing. This simple type of mapping is depicted in Fig. 10. Pseudocolor is also available for the various types of presentations discussed so far. In the pseudocolor mode of DIADS, a particular color is associated with a particular gray level. The corresponding colored picture is then displayed on a CRT of DIADS. This can be a very effective mode. The chromaticity threshold curve, Fig. 3, suggests that interactive optimization of the pseudocolor grey level association may be desirable and effective for some images. It is likely that DIADS will accommodate this capability as well as provide for picture rotation, regional magnification, and some other aids. The custom program in DIADS which performs the operations just sketched is called JOHNB.

III. HIGH-SEQUENCY BOOSTING

One of the objectives of preprocessing is to optimally prepare the image for interactive mensuration on DIADS. Some of the procedures referred to in the previous section can contribute to the preparation. After this has been done, it is possible to perform additional helpful mathematical operations on the matrix to facilitate mensuration. In this report the procedure of high-frequency boosting

In the domain of mathematics there coexist several complete orthogonal sets of functions. Some are defined over an infinite span of the argument and some over a finite range. The set of Walsh or sequency functions belongs to the latter class. The functions are of simple form having only two amplitude states, +1 and -1. In Fig. 11 a few of the lowest order Walsh functions are plotted along with some circular functions. From this plot the concept of sequency can be visualized as one-half the average number of zero crossings over the range of definition. (The first zero crossing is not counted.) Further, the division of the Walsh set into two groups called CAL and SAL is evident in this plot. Over the last decade a rather considerable corpus of theory and application has developed. These developments are lucidly described in the excellent texts of Ahmed and Rao,[3] Beauchamp,[4] and Harmuth.[5] The simplicity of sequency functions suggests there may be computational advantages in preferring them to some other type. In what follows, sequency analysis is employed to enhance boundaries and lines.

The digitized image matrix can be conceived as sets of vertical and horizontal data sets for which spectral analysis can be performed. Sequency decomposition of the sets, 512 x 512 in number for the present discussion, can then be performed with a fast operator. The result of this is a set of amplitudes for the various allowed sequencies. Sequency decomposition is not limited to the two-dimensional Cartesian space of the present discussion. It can be done in polar, cylindrical, and spherical coordinates. Evidently polar coordinates might be useful for some optical problems having axial symmetry.

The higher sequency amplitudes are naturally related to the features in the picture having relatively small dimensions; e.g., the breadth of a line. If accentuation of the lines or edges is desired, it is reasonable to shift the spectral power distribution toward the high sequencies. This is spectral filtering in the sequency domain. When the redistribution has been completed, a transformation back to the spatial domain is performed. The spectral filtering of images has not been quantitatively formalized. It is largely an empirical process tailored to the particular requirement. In the present work the raised cosine has been employed to roll off the low sequencies and boost the high sequencies.

In brief, then, an interactive program has been developed that utilizes LADIES routines to read in the picture matrix. An option for providing logarithmic stretching of the pixel densities is then presented. The program then requests roll-off and boost parameters. At this point it performs the two-dimensional transformation to sequency space, modulates the amplitudes, and transforms back to the spatial domain. The output is packaged by another LADIES routine for writing on tape. This LADIES routine can also invert the picture, i.e., convert a positive to a negative, or vice versa. The tape output can then be read and displayed by DIADS.

IV. RESULTS

Examples of both piecewise linear density stretching on DIADS and sequency filtering with subsequent display on DIADS will now be considered.

From an oil shale fracturing experiment comes the flash radiograph shown in Fig. 12. The explosion of a charge in oil shale was photographed on the small PHERMEX machine. Figure 12 is a playback of a digitized PDS scan of the original film. The playback was done on the PDS machine. It is possible to barely discern an approximately spherical region where the charge has detonated and also a portion of the detonator wire. In Fig. 13 a DIADS presentation of the picture, with linear stretching by LADIES routines, is displayed. The explosion region is somewhat more easily discernible and the remaining portion of the detonator wire becomes more prominent. In Fig. 14 a picture from the piecewise density-stretching operation is displayed. The wire remnant is now quite conspicuous and some of the explosion cavity boundary has come into better relief. Necessarily, report reproductions are not optimum. A superior reproduction of Figs. 12, 13, and 14 can be obtained by ordering a print of Negative 7720147 from LASL Group ISD-7. An evolutionary sequence illustrating piecewise linear density stretching is shown in Figs. 15, 16, 17, 18, and 19. The original picture in Fig. 15 is a flash radiograph taken on the large PHERMEX machine. Figures 16, 17, 18, and 19 were extracted from a longer sequence. This technique is quite useful in revealing features that might ordinarily escape detection by the trained observer. Pseudocolor is helpful in this technique but is not illustrated here because of report reproduction problems.

The second type of preprocessing procedure is high-sequency boosting. In what follows a negative was processed, but all results have been inverted by LADIES routines. Figure 20 is a DIADS display of the digitizer film. Only modest linear density stretching by LADIES has been performed. The effect of the logarithmic-stretching operation, which is an option in the high-sequency boosting program, is shown in Fig. 21. A significant redistribution of power in the picture has occurred, such that detail formerly obscured is now becoming visible. This redistribution is not anchored to particular features of the picture. It is, however, possible to redistribute the power so that lines and boundaries are accentuated by next applying high-sequency boost. The result is shown in Fig. 22. It is clear that many lines which are poorly visible or invisible in Fig. 20 have risen to marked prominence. Some weak artifacting may be observed in Fig. 22. Sources of some can be found in the original digitized picture matrix by careful scrutiny.

V. CONCLUSIONS

Piecewise-density stretching and high-sequency boosting have been demonstrated to be useful techniques for preprocessing PHERMEX flash radiographic images. They not only facilitate image study by a trained scanner, they are foundations for interactive mensuration on DIADS. Tabular output of the coordinates is one type of DIADic mensuration envisioned. To this end a third and last stage of preprocessing is planned, namely, the elimination of all picture information except the lines to be measured. It is intuitively clear that any interactive mensuration algorithm will have its performance optimized if it has to contend with a minimum of distracting information.

Implicit in the introduction were additional efforts such as optimized pseudocolor to enhance the software capability of DIADS. The performance of DIADS can also be improved by the addition of hardware. Thus, array processors, instructed by optimized dedicated programs, could facilitate image processing and the solution of pattern recognition problems. High-quality, rapid film documentation of the work performed by DIADS is desirable. Hardware which reads directly from DIADS memory and generates such film would facilitate production work and research and development.

ACKNOWLEDGMENTS

I acknowledge with pleasure the generous support provided by S. T. Alexander for software implementation on DIADS. R. C. Bagley performed all of the image digitization operations. W. C. Carter provided the oil shale image. J. R. Breedlove supplied the source picture for the evolutionary sequence. W. R. Oakes, MD, R. Dahlstrom, MD, and J. D. Seagrave provided an introduction to the literature of the human visual system.

REFERENCES

1. Ian Overington, Vision and Acquisition, (Pentech Press, London, 1976).

2. K. H. Ruddock, "The Organization of Human Vision for Pattern Detection and Recognition," Rep. Prog. Phys. 40, 603 (1977).

3. N. Ahmed and K. R. Rao, Orthogonal Transforms for Digital Signal Processing, (Springer Verlag, Berlin, 1975).

4. K. G. Beauchamp, Walsh Functions and Their Applications, (Academic Press, London, 1975).

5. H. F. Harmuth, Sequency Theory, (Academic Press, New York, 1977).

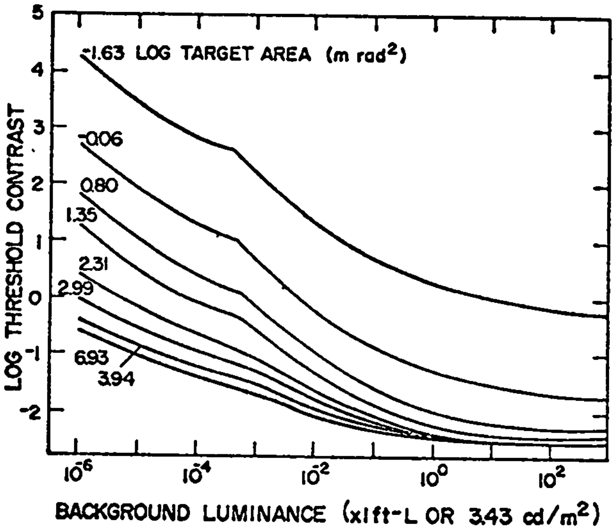

Fig. 1. Threshold contrast as a function of background luminance for disk stimuli. Long viewing time.

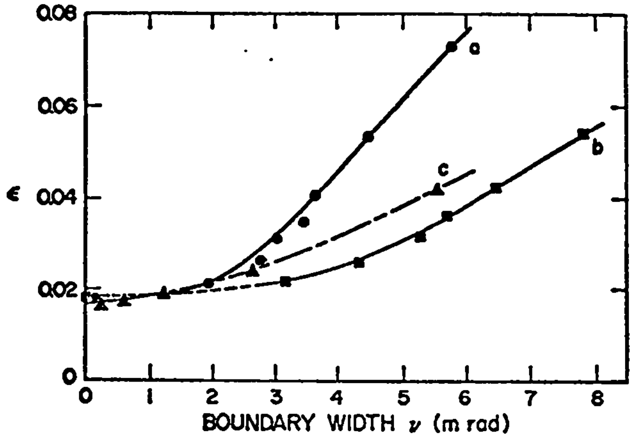

Fig. 2. Effect of a diffuse boundary on detection thresholds. The boundary has a Gaussian form of rate of change of luminance where ν is measured from the 1% to 99% points on the luminance profile. Curve a:ν increasing. Curve b:ν decreasing.

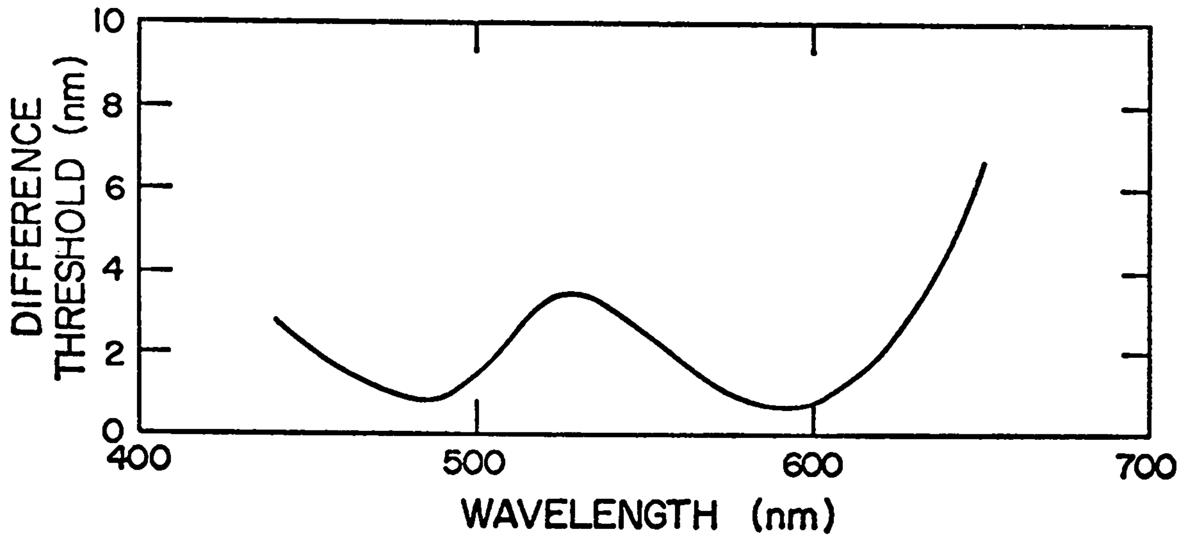

Fig. 3. The variation of differential wavelength threshold as a function of mean wavelength.

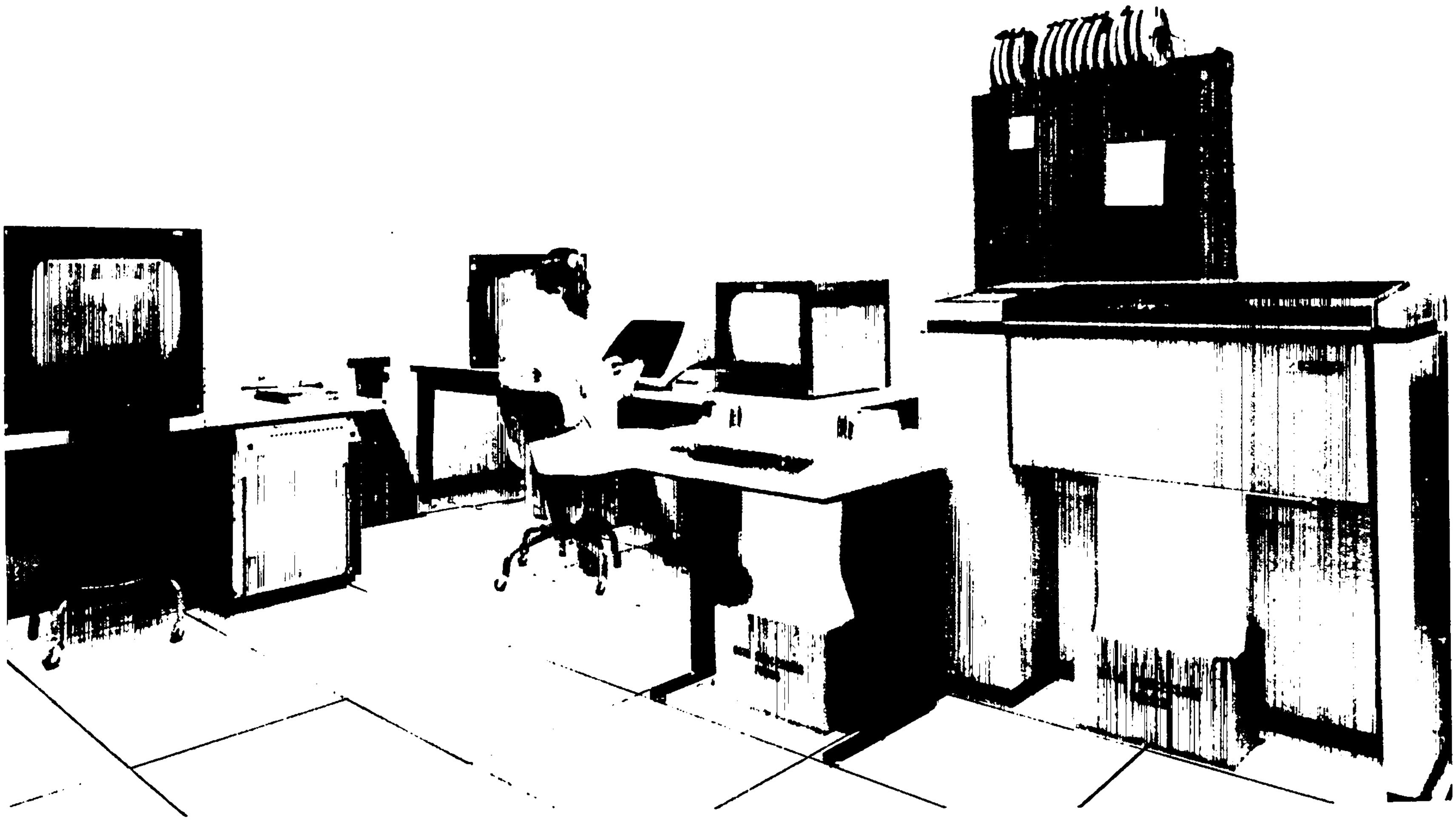

Fig. 4. DIADS control and display units.

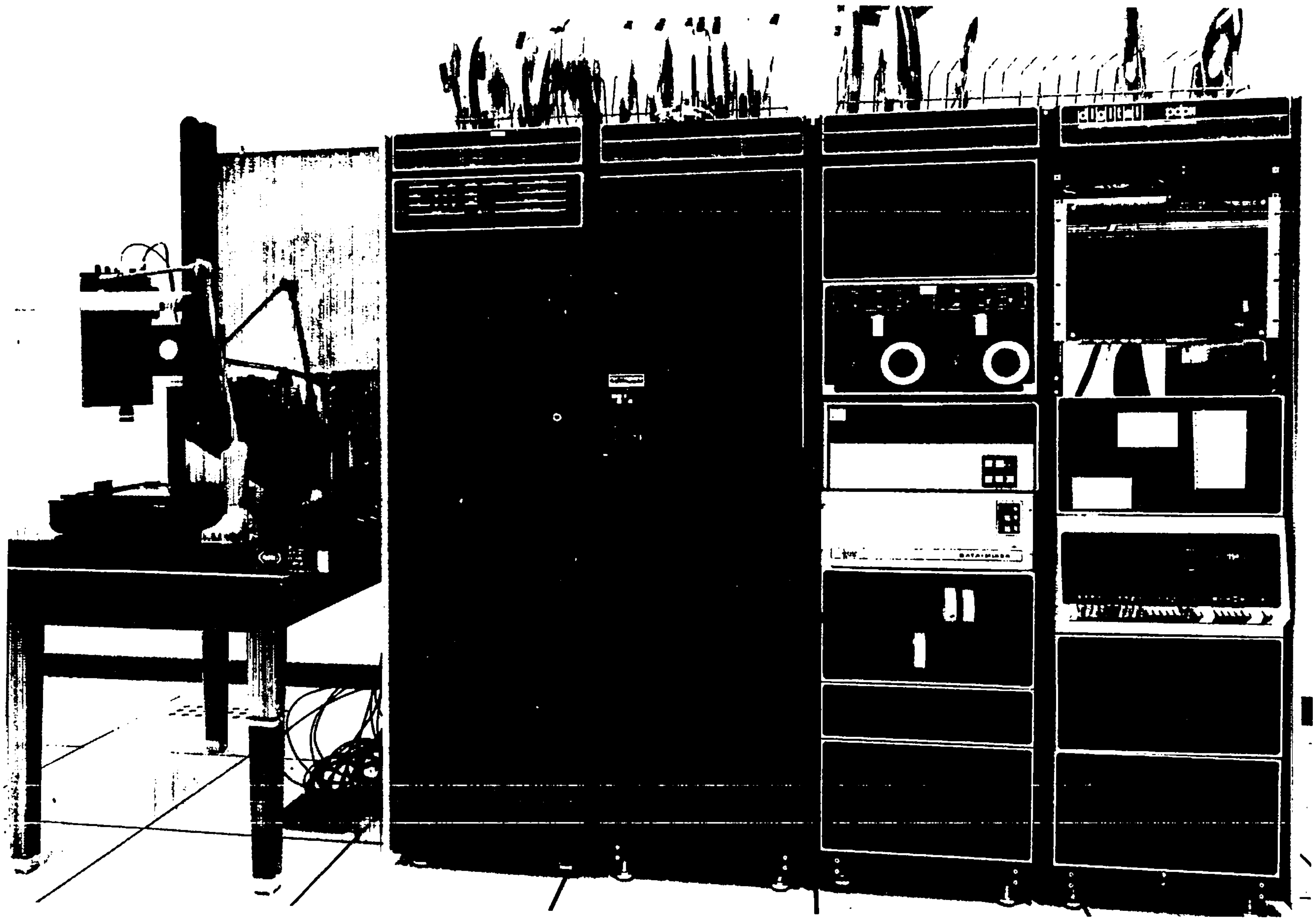

Fig. 5. DIADS principal computer system and SDS picture scanner.

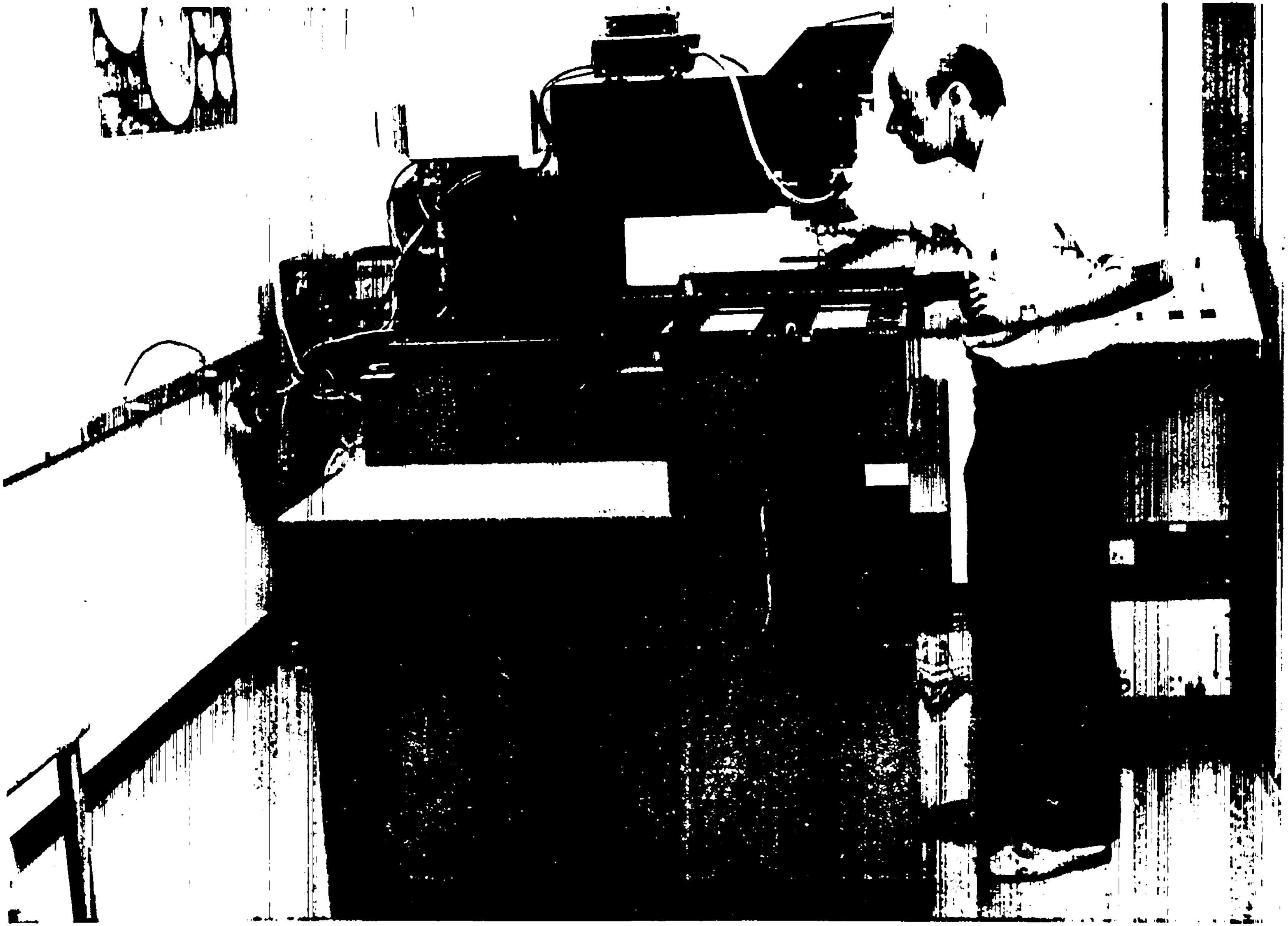

Fig. 6. PDS film digitizer.

Fig. 7. PDS Control and recording system.

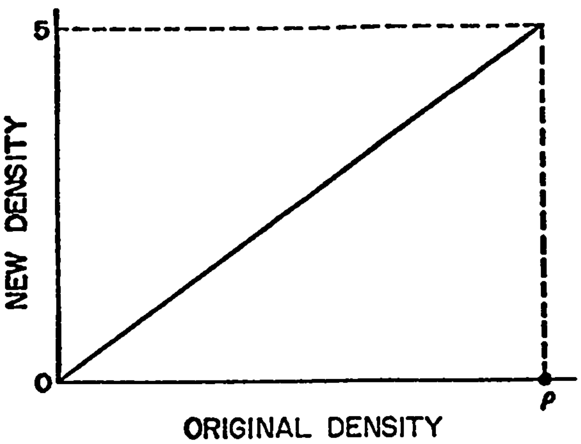

Fig. 8. Linear remapping of film density.

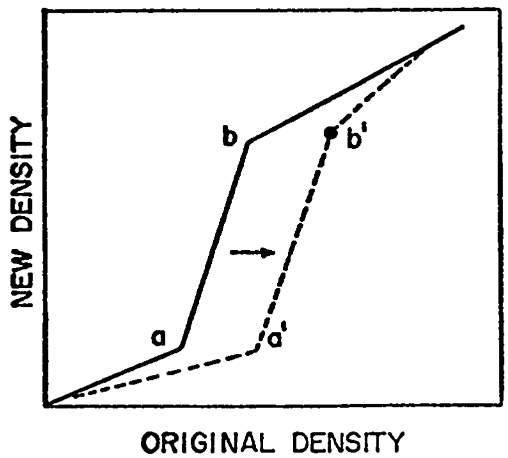

Fig. 9. Piecewise linear density mapping.

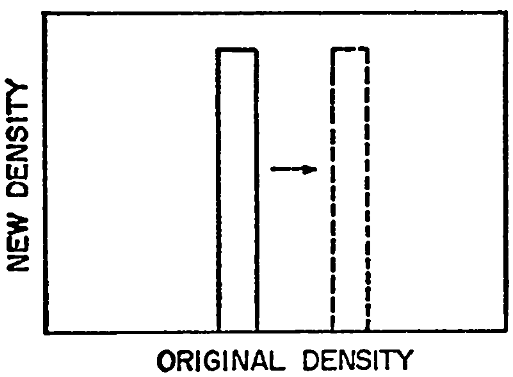

Fig. 10. Density slicing.

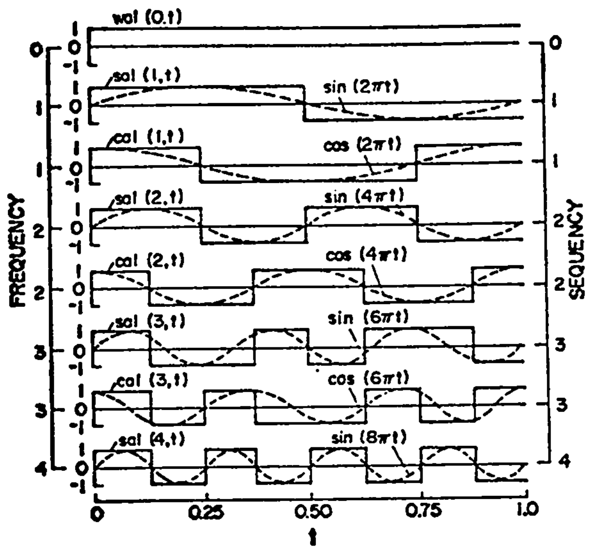

Fig. 11. Comparisom of Walsh or sequency functions with circular functions. Sequency appertains to Walsh functions and frequency to the sines and cosines.

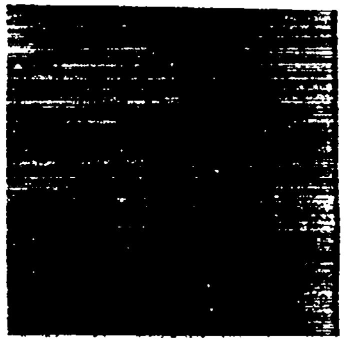

Fig. 12. Playback of oilshale film.

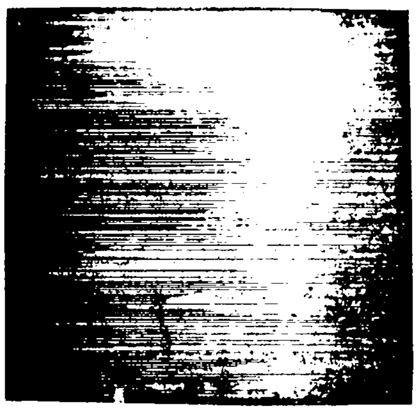

Fig. 13. Linear stretching of the oilshale picture.

Fig. 14. Piecewise linear density stretching of the oilshale picture.

Fig. 15. Original picture digitized on a 512 x 512 matrix.

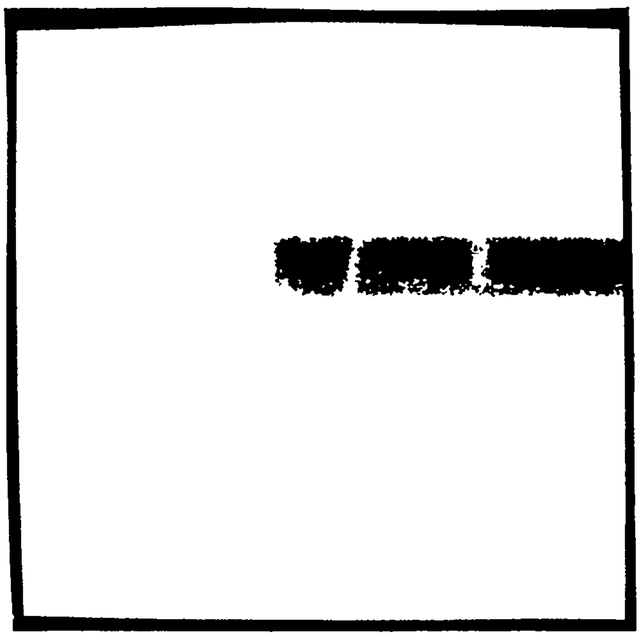

Fig. 16. First piecewise linear density stretching (PLDS) of Fig. 15.

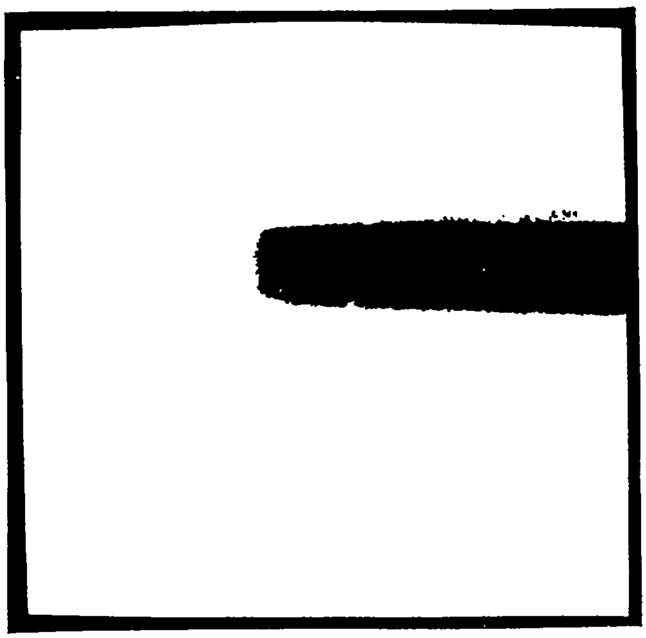

Fig. 17. Second piecewise linear density stretching (PLDS) of Fig. 15.

Fig. 18. Third piecewise linear density stretching (PLDS) of Fig. 15.

Fig. 19. Fourth piecewise linear density stretching (PLDS) of Fig. 15.

Fig. 20. Original picture displayed on DIADS. It is digitized on a 512 x 512 matrix.

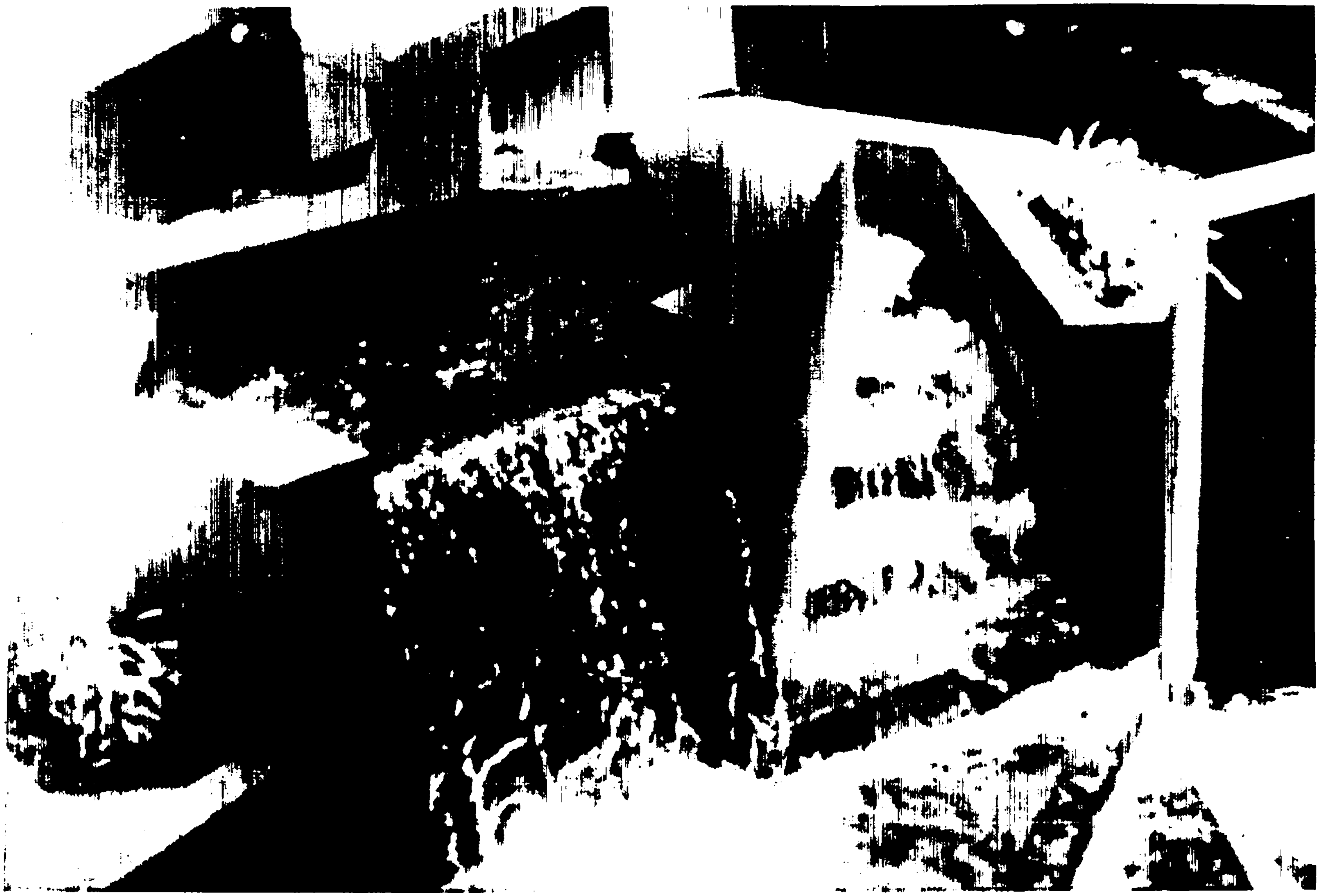

Fig. 21. Logarithmic density-stretched version of Fig. 20.

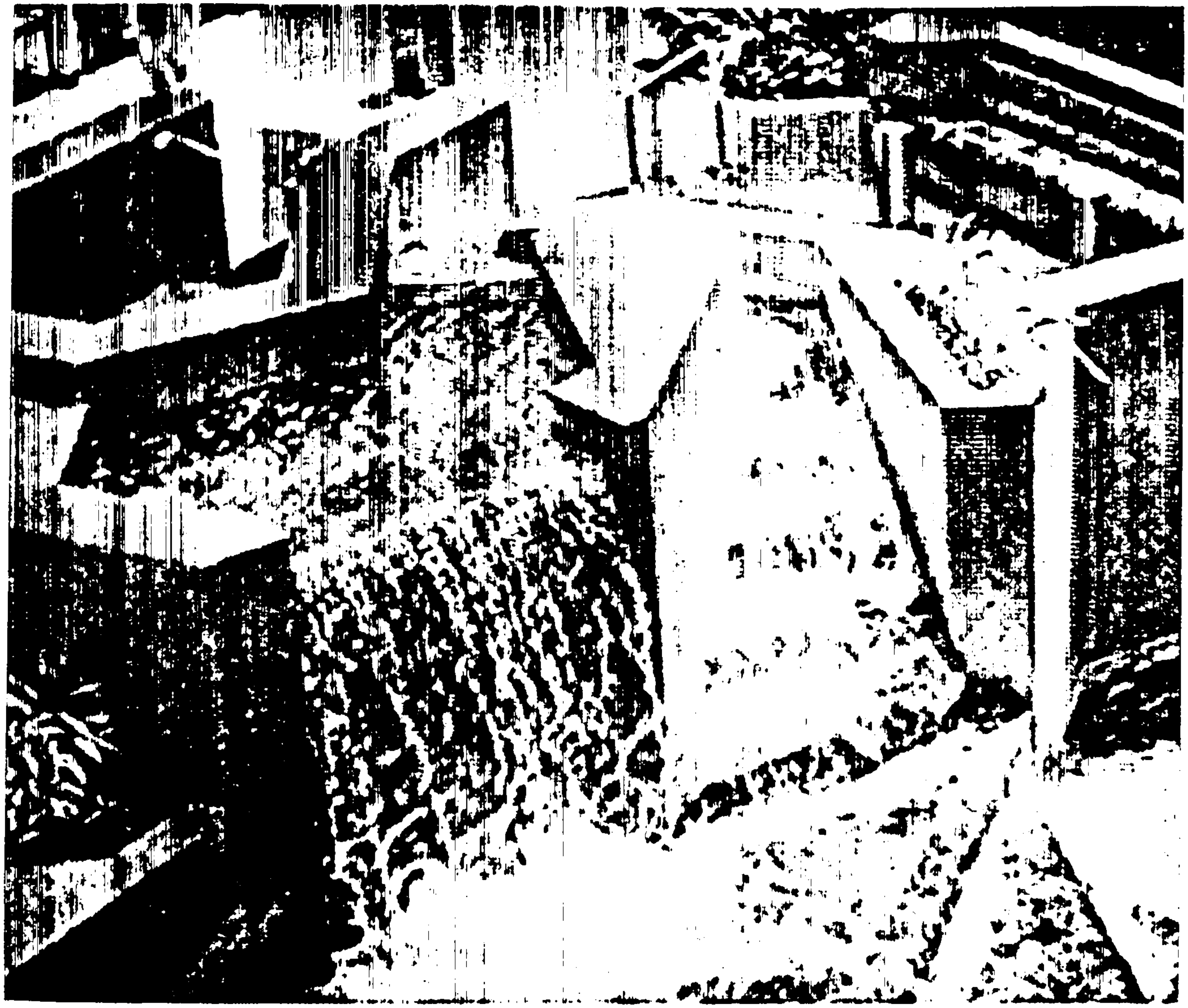

Fig. 22. Logarithmic density-stretched, high-sequency boosted version of Fig. 20.