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I. TITLE OF REPORT: Automatic Data Extraction of Earth Resources Information from Skylab Imagery of S.E. Spain

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SUMMARY OF SIGNIFICANT RESULTS

The use of television microdensitometry using the Quantimet 720 system by Image Analysing Computers, allows rapid density slicing to be carried out, instant readout of areas and number of features depicted as well as having several other characteristics which can be usefully exploited for analysis of orbital imagery. It is, for many orbital applications, preferable to conventional electro-mechanical methods of microdensitometry, which although they are capable of making very accurate individual measurements, they are generally too slow to allow the accumulation of data from the large populations of the many images required for reasonable statistical accuracy. The unique image editing facility enables human intervention in the pattern recognition process, and also enables the mixing of different spectral bands to be carried out quantitatively in an objective manner, as opposed to the subjective nature of image mixing techniques used in visual stereoscopic analysis. This highly interactive ability of the image editor has been observed to be preferable to the fully automatic pattern recognition approach for most aspects of natural resources surveys.

INTRODUCTION

Having used with limited success both conventional microdensitometers such as that produced by Carl Zeiss Jena, and the Isodensitracer marketed by Joyce Loebl, it was considered necessary to experiment with faster systems of image analysis, and ones which would be more versatile and quantitative.

The Quantimet 720 Image Analysing Computer was examined to assess its usefulness for the analysis of Skylab photography of S.E. Spain.

THE SYSTEM

Basically the Quantimet 720 Densitometer consists of a microscope which projects the specimen image on to the face of a special purpose vidicon or plumbicon scanner. The video signal generated by the scanner is passed to the system control in the central processor (Figure 1) and the image is then digitised spatially into a fixed matrix of 500,000 picture points. The densitometer determines the light absorption independently at every picture point and assigns to each a six bit binary code between 0 and 63, equivalent to the true log of the optical absorption at that point, i.e. the optical density. A range setting switch multiplies this code by 0.01, 0.02 or 0.04 and so the full range of resolvable measurement under normal circumstances is the optical density range zero to 2.52. The optical density contribution of each picture point in a selected area is then summed to give the total integrated density for the area and the result can either be read off from the screen display or routed to an output peripheral such as a teletype or desk top calculator.

BASIC MEASUREMENTS

The Quantimet 720 system can make the following basic measurements of value to earth resources studies using Skylab imagery.

(i) Number:

It counts the total number of features in a field of view (e.g. the number of agricultural fields, irrigated and dryland farming areas) or the number of these per unit area, e.g. density or intensity of land use in a particular area.

(ii) Area:

It measures the total or mean area of all pre-selected features or the area of any individual features in a field of view.

(iii) Optical Density:

Measures the integrated optical density of all selected or of individual features in a field of view.

(iv) Pattern Recognition:

Selects features by shape and other geometric or densitometric criteria, before carrying out any of the above mentioned measurements of them.

DETECTION RANGE

In the first instance, accurate image analysis depends upon the precise detection from the background of only those features which are required to be measured.

Earlier image analysing computers used conventional television cameras based on standards designed to optimise the scanning and transmission of moving pictures - their scan rate was around 50 frames per second and they used 525 lines (in the U.S.A.) or 625 lines (in Europe), scanning on only half of these in any one frame scan (i.e. they used interlaced scanning).

These television standards do not realise the full resolution and signal to noise performance available from vidicon or plumbicon tubes.

The Quantimet 720 abandons television standards and incorporates new purpose-built, slow speed scanners, using 720 scan lines and 10.6 frames per second, with no interlace, specifically designed to optimise the precise and accurate image analysis of static fields of view. These scanners, used with the automatic matrix shading corrector, ensure that electronic noise, and shading, caused by positional variations in illumination and scanner response, are minimised, and that detection is uniform across the field of view. They thereby enable more than thirty separate grey levels to be detected to better than 1% accuracy over the whole field of view.

Moreover, once selected features have been isolated for measurement, an automatic detector ensures that they are measured exactly, by locking on to the precise boundary of each feature.

Figure 2 shows the city of Murcia (population 250,000) as it appears on the black and white panchromatic photograph taken with the S190A camera on Skylab, enlarged to a scale of 1:1,000,000.

Figure 3, however, shows how, by using the density slicing facility available on the Quantimet, the urban area may be more readily distinguished. Now also, all the main roads and linear settlements leading into the city are clearly visible.

PATTERN RECOGNITION

Figure 4 shows the Quantimet 720 system with various automatic detection and pattern recognition modules added. These greatly increase the complexity of earth resource applications that the machine can handle.

The automatic detection module automatically selects the correct detection threshold for each feature at 50% of its peak grey level above the background, so eliminating threshold setting errors. The pattern recognition modules allow measurement and classification of features by perimeter, area, vertical and horizontal projection length, Feret's diameter and maximum length. They also allow features to be picked out by their shape, or by virtue of the presence of other features within their boundaries. For instance, circular features may be discriminated from acircular ones on geometric grounds by the pattern recognition modules. These various discriminatory functions may be combined in many ways, depending upon the sophistication of the discrimination required, such as urban area development, drainage network analysis, vegetation and land use mapping, and water resources.

The Quantimet 720 Pattern Recognition System considers each feature in a field individually and measures its area (A), perimeter (Pe), projected lengths (P_h and P_v), Feret diameters (F_h and F_v), optical density (D).

Features can be classified by any of these parameters but, in addition, measurements for each feature can be combined to define shape factor ratios for feature recognition and separation before classification.

Typical form factor ratios are indicated in Figure 5.

Diagram 6 summarizes the main processes and applications involved in the pattern recognition system.

One of the most useful features from an earth scientists' point of view is the image editing facility which is available with this instrument. It provides a useful interface between simple visual interpretation of the terrain and automatic pattern recognition. Image editing is done with a light pen, used in the same way as a drawing pencil. The operator can, therefore, intervene directly in the analysis process of the orbital image, to obtain exactly the data required. This interactive ability of the image editor has been observed to be preferable to fully automatic pattern recognition systems, especially because of the variance in the parameters used, inherent in most natural resources as depicted on orbital imagery.

OPERATION

The image editor module has three basic operations.

(i) Edit:

Which allows the operator to change the image before measurements are made.

(ii) Photo:

Which enables a detected or the edited image to be stored.

(iii) Mix:

Which allows the operator to interact the stored image with new detected or edited images.

The operator can:

(a) Outline selected regions for measurement, e.g. watershed divides.

(b) Reject unwanted regions.

(c) Fill in imperfectly detected regions, which is otherwise a common problem in density slicing of natural resources.

(d) Separate touching or overlapping features.

(e) Draw in additional lines or features, e.g. drainage networks, roads, etc.

(f) Correct any mistakes made in editing.

(g) The image editor module also enables the detected image to be stored, so that it can be interacted with subsequent images in a number of useful ways. This mode of operation has been found to have many applications in the analysis of dynamic situations, e.g. in comparisons between multispectral images from Skylab.

Thus the image editing facility overcomes one of the drawbacks inherent in most other densitometer systems, namely the limitation of the system in being restricted to analysis of one spectral band. Now, it becomes possible to store the data, and hence make multispectral comparisons of both the various photographic products of Skylab such as the S190A multiband camera system, and the 13 band multispectral scanner system.

Selection of the operating mode is simply achieved by pointing the light pen at the appropriate action on the list of modes which appears on the display, as illustrated in Figures 7 and 8.

Another useful editing facility is the ability to draw in clear new boundaries and other outlines, such as poorly defined forested areas, geological structures which have many kinds of image detail mixed together, etc.

IMAGE MIXING

Image mixing by conventional photo interpretation techniques using zoom stereoscopes has been described in detail in a previous report by the author (see references at end). The Quantimet system allows this to be done in a more objective, systematic manner. Diagram 9 shows how it can interpret and analyse two different spectral bands from Skylab.

In the mix operation, the Skylab image can be interacted with other new images in a number of useful ways as illustrated in Figure 9. The selection of the operating mode is done by pointing the light pen at the appropriate section on a new list which appears on the display.

The main applications to earth resources surveys of the various operating modes depicted in Figure 9 are:

(i) Accept Mode:

Picks out common points. Differentiates between objects having same size and those that have changed in position, e.g. fluctuating lake levels, change in agricultural land use, especially increases in areas under irrigation in Segura river basin.

(ii) Reject Mode:

Picks out increases - shows new detected areas - similar applications to above.

(iii) Diff Mode:

Shows both increases and decreases, i.e. shows total change, and hence ideally suited to sequential orbital coverage for systematic appraisal of changes in land use throughout season, water resource appraisal of the numerous lakes and reservoirs (NASA report, see references).

(iv) Cover Mode:

Shows detail from either image - very useful for spectral comparisons when used with 13 band multispectral scanner data.

(v) Erase Mode:

Shows stored image erased by new image.

Thus the speed with which density slicing, area measurements and automatic pattern recognition, or semi-automatic image analysis using the editing facility, can be greatly increased by using the Quantimet 720 Image Analysing Computer.

REFERENCES

GENDEREN, J.L. van (1974): "Stereo Study as an Aid to Visual Analysis of ERTS and SKYLAB Images." (NASA-CR-139253, 10 pages).

GENDEREN, J.L. van (1974): "Hydro-Geological Data from Skylab EREP Imagery of the Murcia Province, S.E. Spain." (NASA-CR-139630, 38 pages).

GENDEREN, J.L. van (1974): "An Evaluation of Stereoscopic Viewing of ERTS and SKYLAB Images." (European Earth Resources Satellite Experiments, ESRO, Paris, pp. 48-55.

GENDEREN, J.L. van (1974): "The Interpretation of Orbital Imagery using the Interpretescope of VEB Carl Zeiss Jena." (The Jena Review, No. 3, pp. 177-181) Also published in French, German, Spanish and Russian.

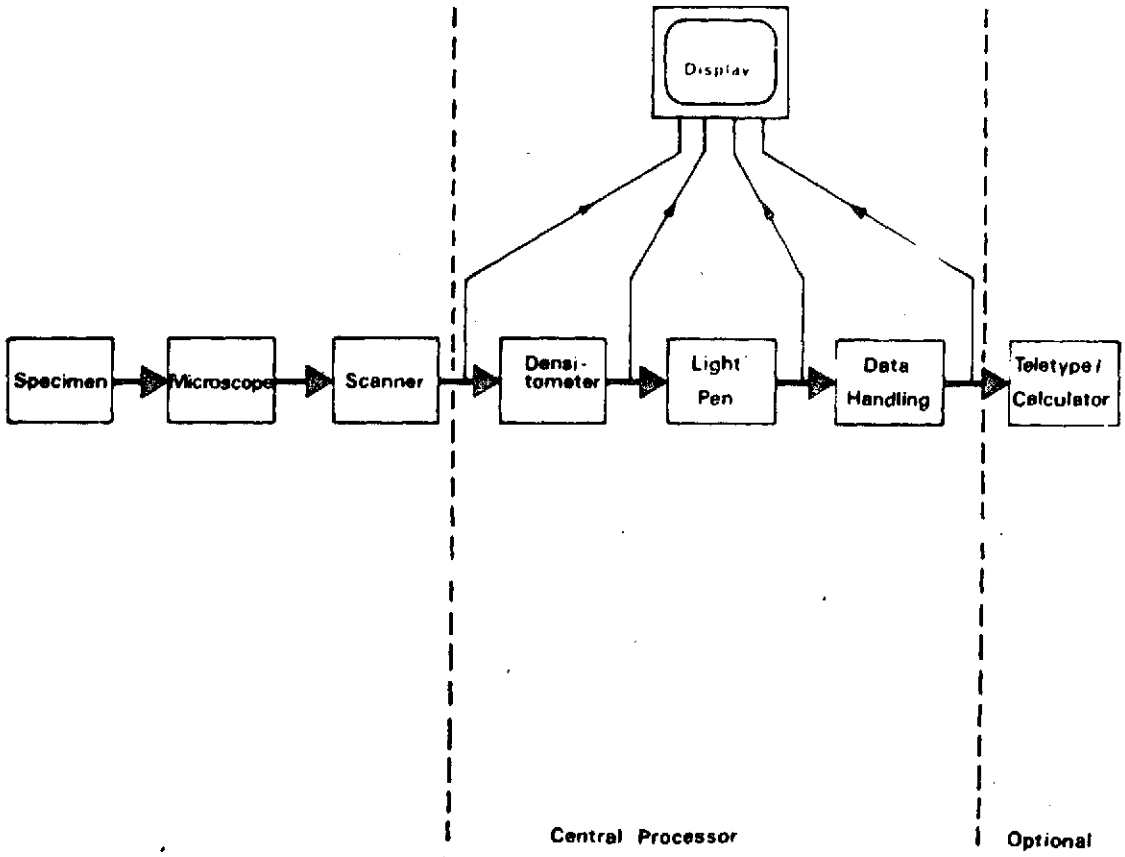


FIGURE 1: The Quantimet 720D Block Diagram.

FIGURE 2: City of Murcia (population 250,000) as it appears on the black and white panchromatic photograph taken with the S190A Camera on Skylab, enlarged to a scale of 1:1,000,000

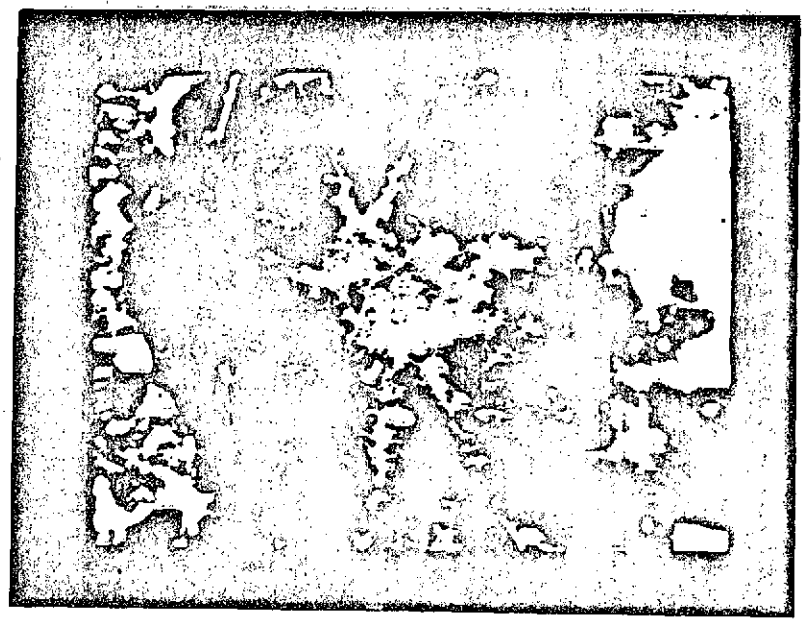


FIGURE 3: Density slicing to enhance detection and delineation of urban areas and roads.

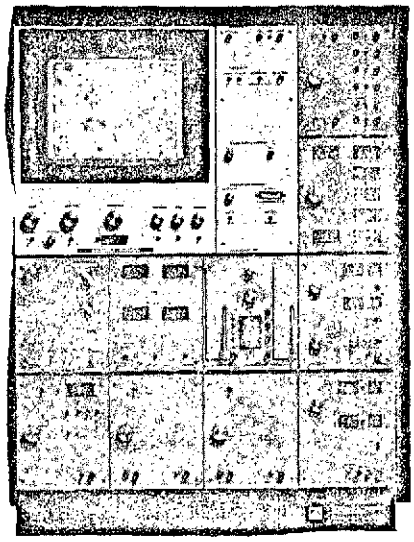


FIGURE 4: The Quantimet 720 system with various automatic detection and pattern recognition modules added.

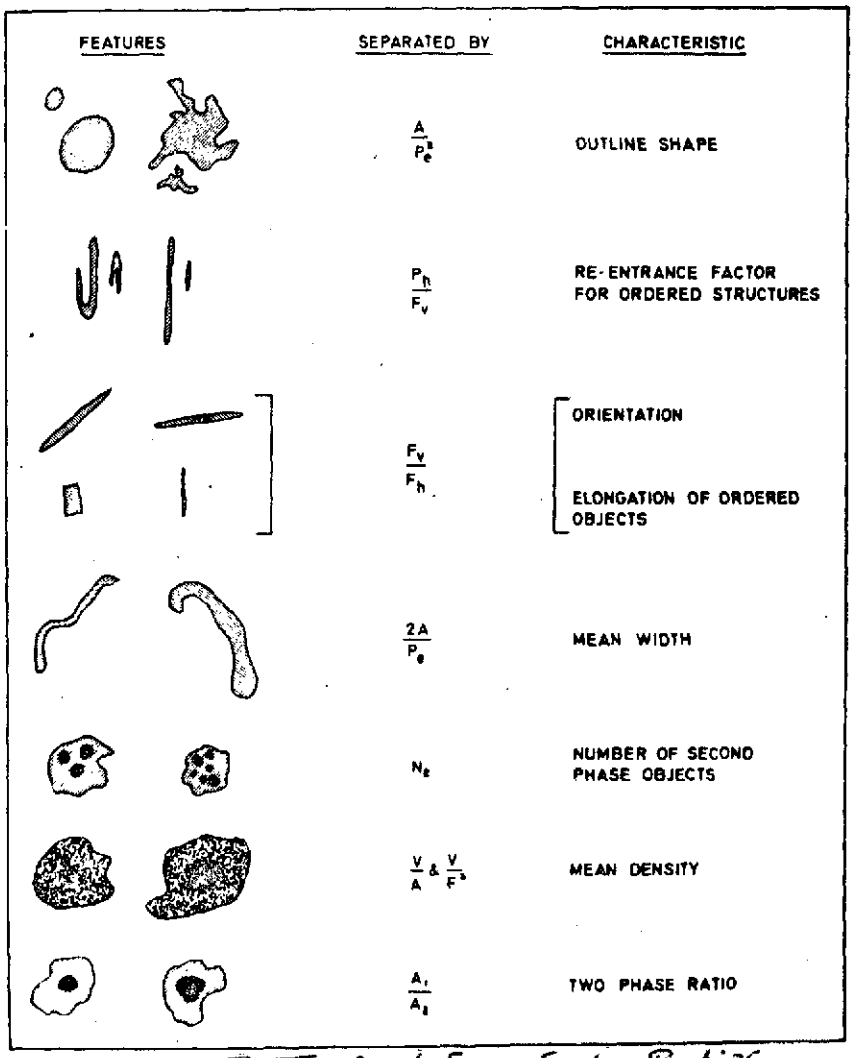
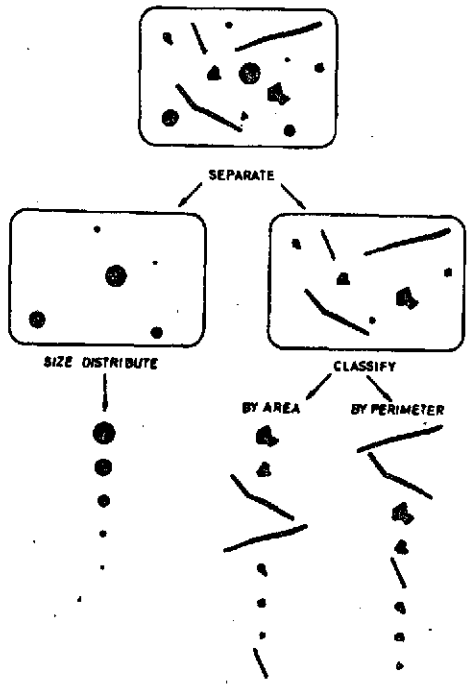


FIGURE 5: Typical Form Factor Ratios.

Quantimet 720
Pattern Recognition Systems



MAKE GEOMETRIC AND DENSITOMETRIC CLASSIFICATIONS AND MEASUREMENTS ON ALL FEATURES IN A FIELD OF VIEW - SEPARATELY, SIMULTANEOUSLY, INSTANTLY

- TRUE AREA SIZING
- SHAPE CLASSIFICATION
- CLASSIFICATION BY DENSITY
- SIMULTANEOUS OPERATION AT MANY GREY LEVELS

FIGURE 6: Main processes and applications involved in Pattern Recognition system.

OPERATING MODE

Edit (to modify originally detected detail)

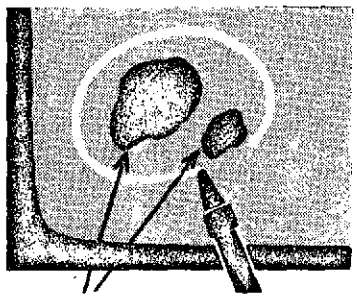
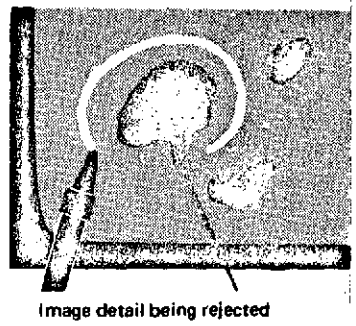
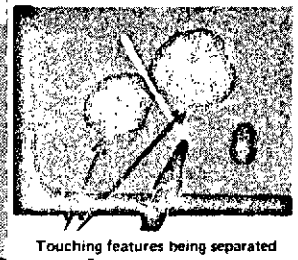
	Accept	Reject	Cut
	 Image detail being accepted	 Image detail being rejected	 Touching features being separated
Operation	Only detected detail which is inside a closed line drawn with the light pen on the display is accepted for measurement.	Any detected detail inside a closed light pen line drawn on the display is rejected from measurement.	Any detected features which are cut across by lines drawn on the screen are divided into separate features by the lines. Allows touching detected features to be separated.
Purpose	Selects detail for measurement where it is otherwise impossible to select by grey level discrimination or by Quantimet pattern recognition techniques.	Rejects unwanted detail from measurement where it is impossible to discriminate against such detail by grey level detection or Quantimet pattern recognition techniques.	

FIGURE 7: Image Editing - Edit Mode.

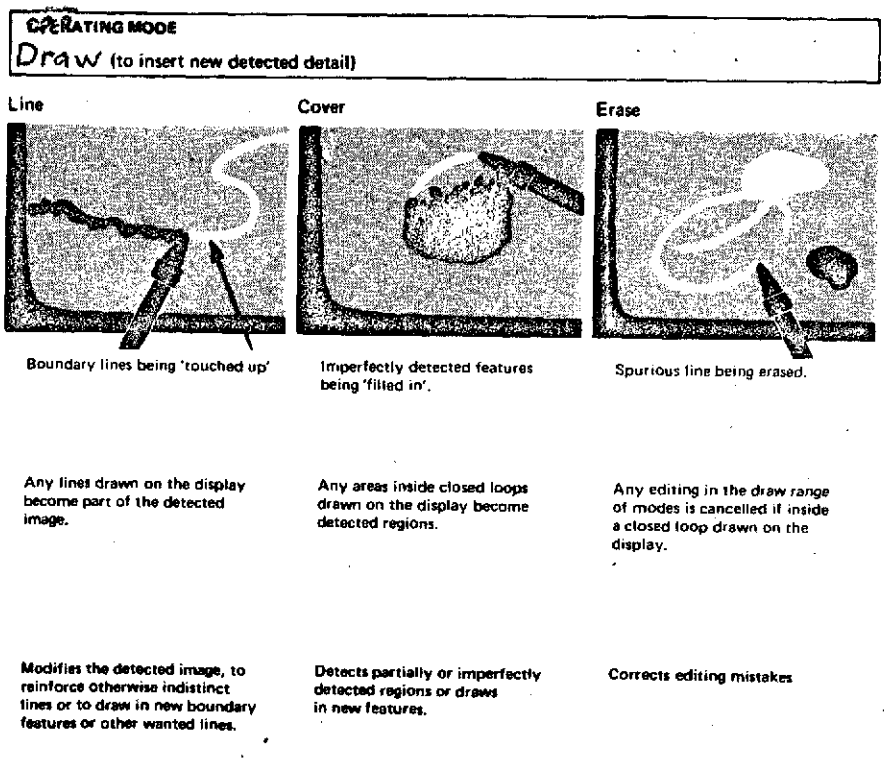


FIGURE 8: Image Editing - Draw Mode.

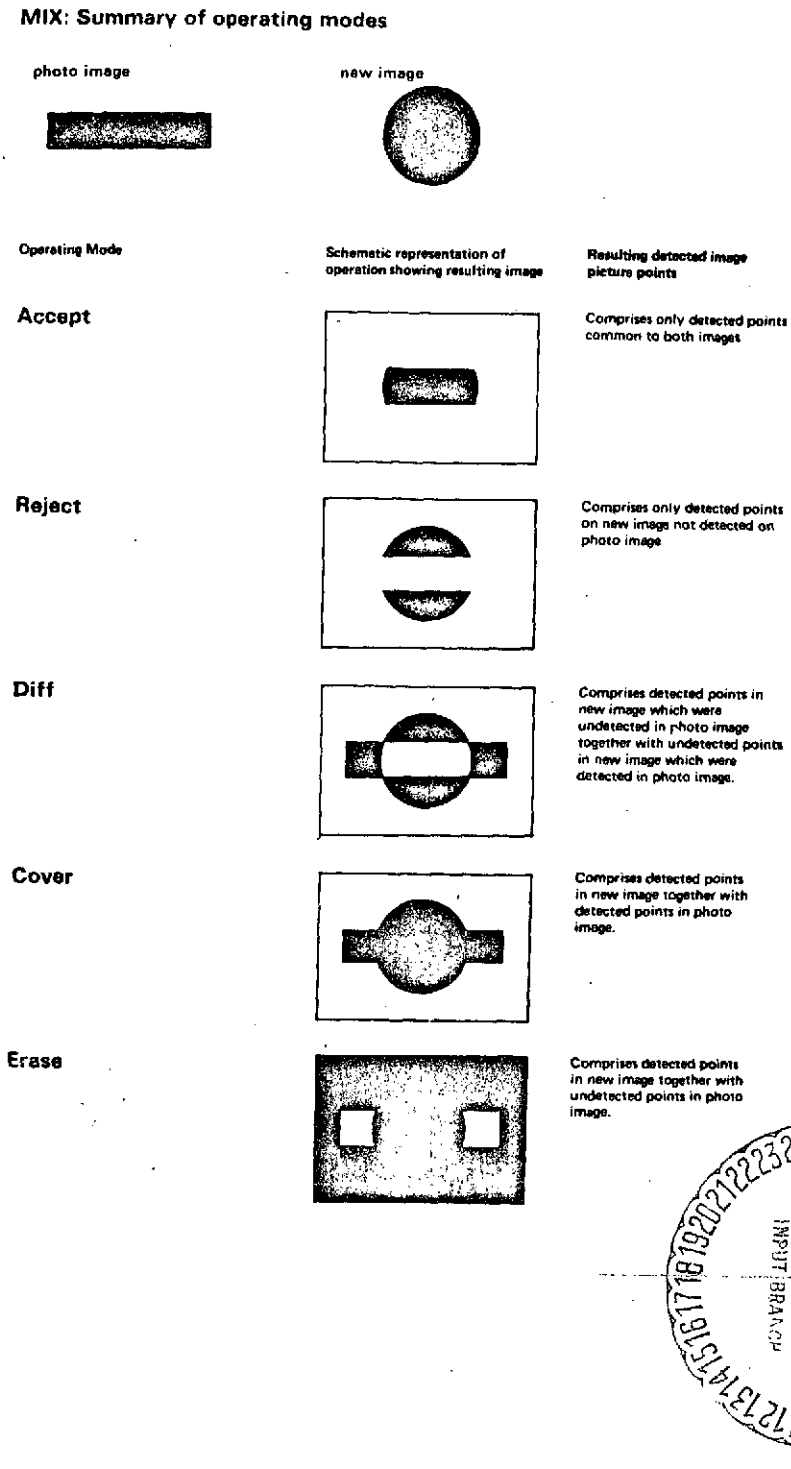


FIGURE 9: Image Mixing by the Image Editor.