PREPROCESSING PROCEDURES FOR AUTOMATIC PLOTTING IN PHOTOGRAMMETRY

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1. Introduction

In the last few years a new photogrammetric methodology has been studied for particular applications in close range photogrammetry; generally it is called raster-photogrammetry.

The methodology requests that a reticle is projected onto the object to be taken and it has mainly two advantages: it needs only one photogram instead of the stereoscopic pair and it makes easier the automatic reading of the plate-coordinates and consequently the automatic plotting.

The reticle we have employed consists of a double series of bright straight lines intersecting in points called nodes.

In order to obtain a precise raster photogrammetry we need especially a precise projector during the taking. Then, if we proceed with automatic reading of plate-coordinates, we need to acquire the image and then to process data with a digital computer.

In this paper we report about the projector, the scanning device and the preprocessing procedures.

In ref.[1] an example of plate-coordinates reading is shown, which was performed on data that have been acquired by using some devices and the preprocessing procedures described in the following.

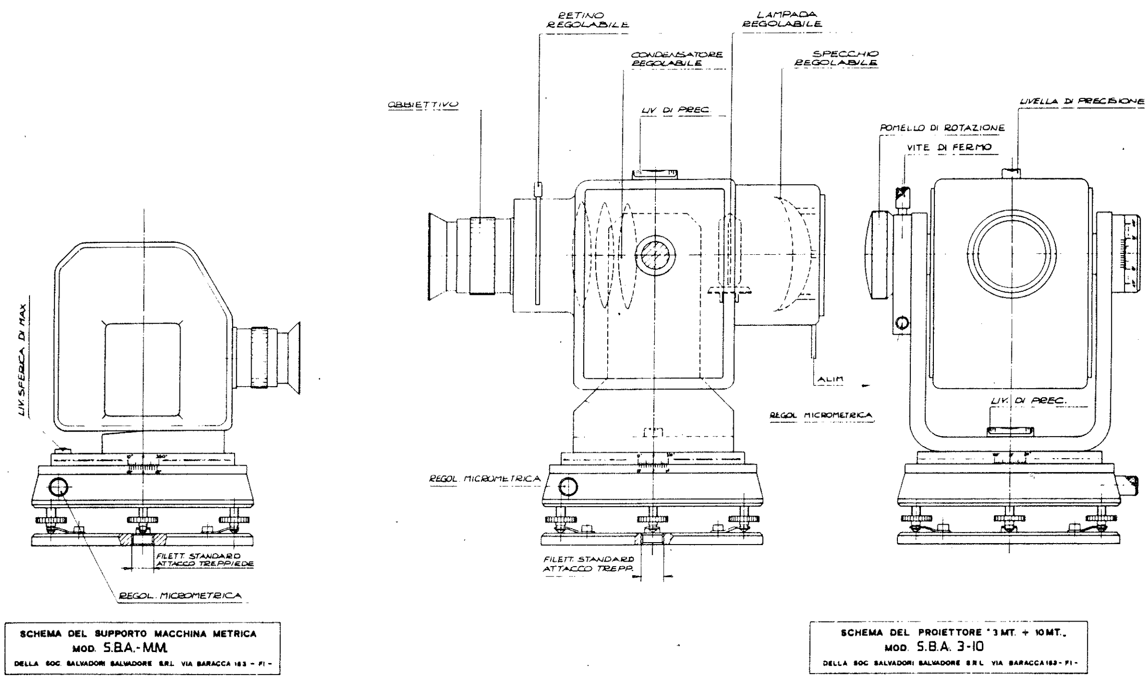
2 The Projector

The projector is really different from a normal one; we will call it "metric projector".

First of all it will have the same precision of the metric camera it works with (from the mechanic point of view as well as from the optic one) and it will work on a tripod.

As it is very important to direct easily the projector towards the object to be taken, it will consist of two main parts: an orientable support and a tiltable projector; these rotations, measurable on horizontal and vertical circles allow the projector to assume the exterior orientation requested (fig.1).

In a metric projector, like in a metric camera we have to define the interior orientation, i.e.:a) principal distance; b) princi-



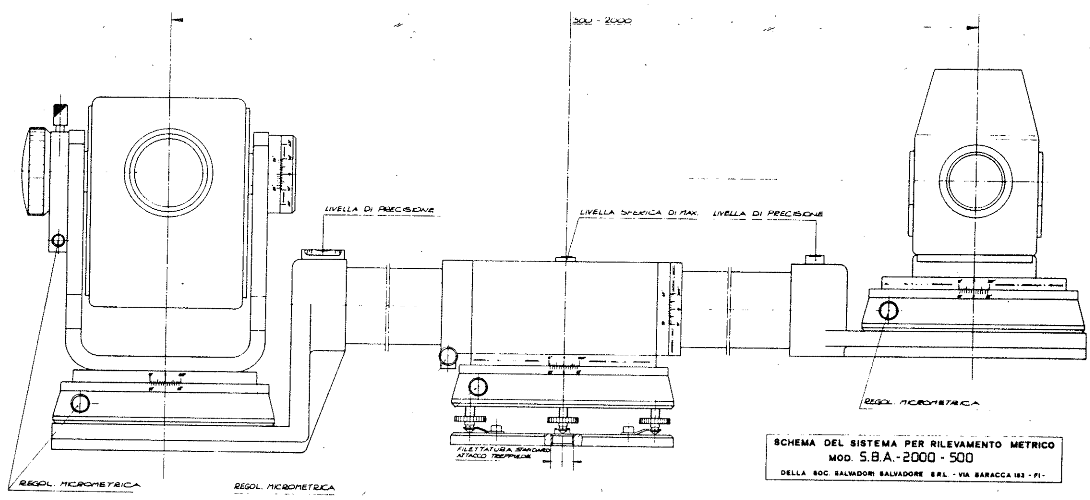


Fig.1 and Fig.2: Drawings of the metric projector and of the photographic assembly.

pal point; c) and the coordinates of the principal point.

a) We define principal distance as the distance from the internal perspective center (nodal point) to the plane of the reticle measured along the perpendicular to the plane of the reticle: the perpendicular has to be coincident with the optical axes of the lense. This distance is variable in discrete steps according to the possibility of the metric camera the projector works with.

b) We define principal point as the foot of the perpendicular from the interior perspective center to the plane of the reticle. The reticle, that is coated on an optical glass, is mounted on a frame: the frame is put in situ always in the same position. On the frame there are reference points which, when properly connected, determine the X,Y axes: these reference points have to be coincident with particular ones on the edges of the reticle.

c) We define coordinates of principal point as those determined with reference to the X,Y reticle axes. The reticle as mentioned before is made up of two series of parallel lines intersecting at 90° in point called nodes: the lines are bright on a black background.

Actually in raster-photogrammetry the reticle or pseudo-photogram has the same function of the second program in normal methodology: for this reason we must have a reference system X,Y, in order to read the coordinates of the nodes.

Besides, it would be advisable that:
1)the principal distance of the camera and of the projectoe were the same,
2)the size of the reticle to be projected were approximately equal to the plate of the camera.

When the above conditions 1), 2) are satisfied, we can take, by converging the optical axes of the camera and of the projector, all the illuminated aıea onto which the reticle is projected.

Actually as we will not employ a plotting device with a human observer we have not to limit the angle of convergence to a few degree as generally requested.

Moreover camera and projector can be mounted at the ends of a horizontal base supported by a special tripod: the base lenght can be varied from 700 mm to 2000 mm (see fig. 2).

This equipment is very usefull for close-range standard survey: when the survey is done in almost the same conditions and it regards objects of the same size and morphology.

The base can be oriented with azimuthal direction according to viewing conditions: moreover the device can rotate around the ba se horizontal axis of ± 90°, so that vertical views, up and down oriented can be obtained.

With a few exceptions, stereometric cameras are rigidly mounted on a base with optical axes parallel to each other and perpendicular to the base, while in our case the projector axis is free to rotate relative to the base so that convergent views can be carried out and the whole surface, onto which the reticle is projected, can be taken.

3. The Acquisition Process

A typical procedure followed in raster photogrammetry is shown in fig.3.

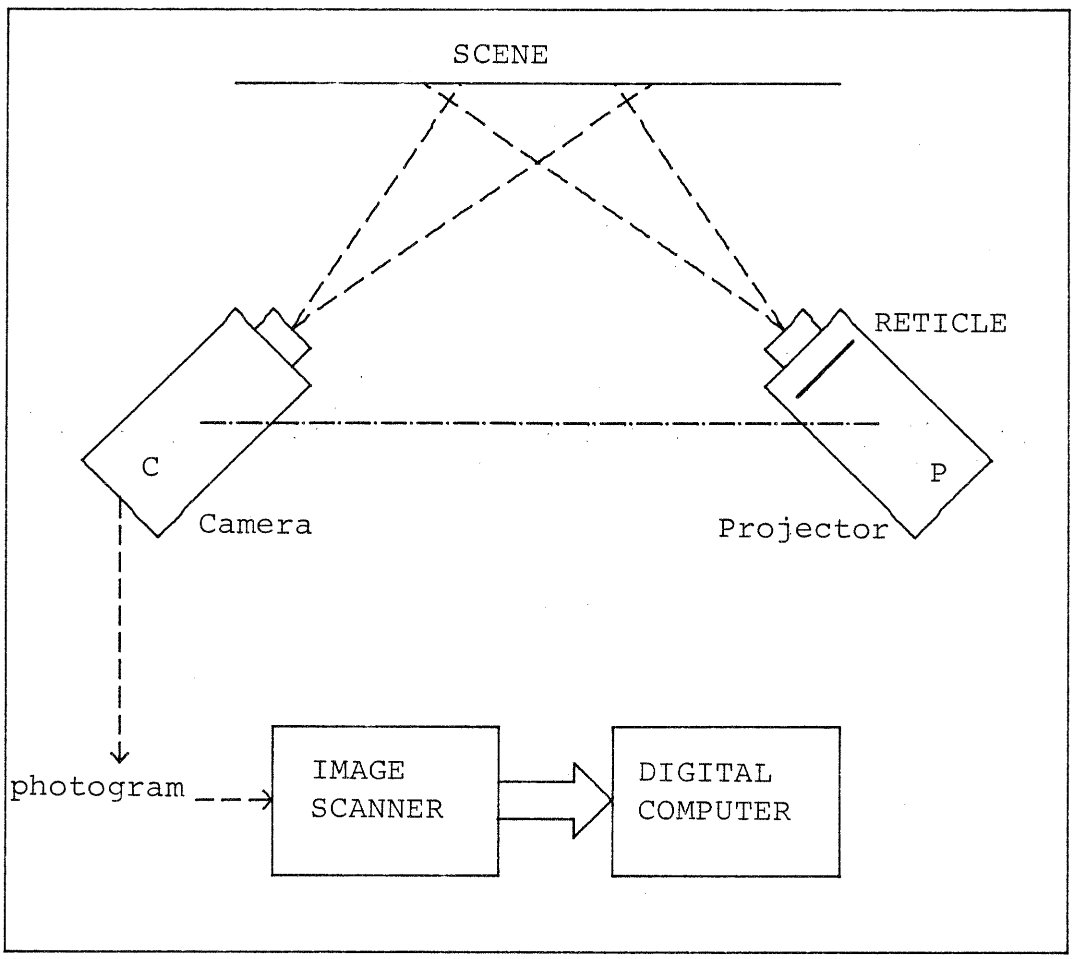


Fig.3: Acquisition procedure in raster photogrammetry

Firstly a bright reticle is projected by the projector P onto the object to be analyzed, and a photogram of the scene is obtained by using the camera C; the photogram is then digitized by a scanning device, so that a matrix is obtained whose elements are associated to the image pixels: this matrix (digital image) is then processed by the computer.

Theoretically, the digital images to be processed are static, monochromatic and graphical, so that the intensity F can only assume two values:

$$F(x,y) = \begin{matrix} f_0 \\ f_1 \end{matrix} \quad \text{, where X,Y are the plate coordinates}$$

Actually, the MTF functions of the optical components employed in the whole process of image formation and acquisition (projector, metric camera, photographic support, digitization device) will degrade the quality of the signal to be acquired, in such a way that the digitized data are defined by a multi-value discrete function.

In order to restore a two-values function which allows an automatic reading of the plate-coordinates, a set of preprocessing procedures must be executed on raw data.

The sequence of the procedures is the following:

P1: detection of all parameters necessary to correct photometric and geometric distortions;
P2: data correction;
P3: filtering;
P4: detection of the thresholding value, in order to obtain a two-value matrix;
P5: thinning of the lines contained in the two-value matrix.

Besides, data relative to the reticle reflected by the examined object cannot be generally extracted from one single photogram; in fact, the informations about the reticle (that is, the signal to be detected) are mixed with the informations about the object itself (which has to be considered as noise).

In order to solve this problem, a pair of photograms have to be taken under the same conditions; the one, with the object alone, the other one with the reticle projected onto the object; the informations about the reticle are then obtained by subtracting the pair of digital images. Consequently, the following procedure must be performed:

P0: registration and subtraction of the two matrices.

In the following the resources and the procedures used to analyze a sample image are described.

4. The Processing Structure

The architecture of the processing structure is shown in fig.4. The structure is based on three interconnected system.(2)

1) A system oriented to image acquisition from transparent or opaque supports. The main components are:
- H.P.2113 Computer with 640 Kb core memory and disk,tape and printer devices
- MFA's scanners: this is a set of computer controlled microphotometers based on different optoelectronic devices (TV camera -TV-; photomultiplier -FS- and photodiode array -LS).
- Image display: it is a microprocessor based system for the display of 512x512 pixel gray-level or color images.

2) A system oriented to interactive data processing. The main components are:
- H.P.2117 Computer with 1Mb core memory and disk, tape and printer devices.
- Graphic terminal: it is a high resolution storage display with 1024x780 points.

3) A system oriented to automatic data preprocessing. The main components are:
- GOULD SEL Concept 32/27 Computer with 2M core memory, and disk, tape and printer devices.
- Display Computer: it is a microprocessor based system under the control of CP/M Operating System for the manipulation and display of 1024x1024 pixel images.
- Vector Processor MAP 300: it is a computer dedicated to fast parallel arithmetic operations.

The first and the second system above mentioned can inter-communicate by means of a common mass storage area; a serial link connects the H.P.2117 Computer to the SEL 32/27 Computer.

A single high-level language has been implemented on all the systems in order to create a predefined image data processing environment.

5. The Scanning Device

In our case we used the high precision MFA/250/LS Microphotometer, which can measure the optical density transparency of large format photograms. (3)

A sketch of the MFA/250/LS is shown in fig.5. Its main components are:
- an electronic device R, made by a 2048 diodes array Reticon 2048 H and relative electronics;
- a focusing objective O;
- a luminous source S, fixed with respect to the sensor R;
- a film holder H;
- a step-motor assembly M, which supports the plate holder.

The luminous source is parallel to the optoelectronic sensor, and both are aligned along the Y direction of the figure; the

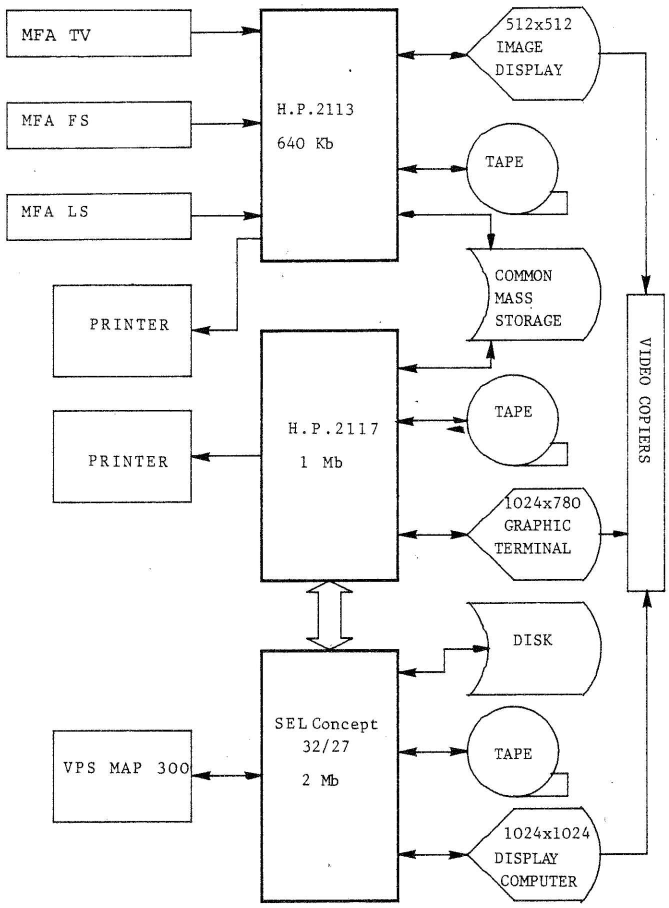


Fig.4: The Processing Structure

sensor receives the luminous flux transmitted by the strip of the photogram actually illuminated by the lamp, so that one row of the image is digitized; the whole image is scanned row by row, according to the shifting of the plate holder along X direction produced by the motorized assembly.

The spatial scanning frequencies are determined by the sensor geometry, the objective charecteristics and the step advance of the assembly. The sensor contains active elements of 15x16 um^2, with 15 um spacing: thus a 15 um sampling interval along X-direction in the sensor plane is obtained, and, due to the magnification M=0,15 introduced by the optics, an effective sampling interval p_x=100 um is obtained in the film plane. Because the linear step of the motorized slider is 100 um, the image is scanned with equal frequencies both in X and Y directions.

MFA-250-LS main features are listed in Tab.1; the device is shown in fig.6.

6. The Procedures

Among the P0 to P5 procedures above mentioned, we will describe only P4 and P5 procedures, which are of particular interest for our purposes. (4)

6.1 Thresholding Procedure

As already mentioned, the graphic image of the reticle, made ideally up of a homogeneous background and of a set of simple curves, after the acquisition process, is degraded into an image whose pixels have photometric values distributed over a continuous scale and whose geometric lines are approximately defined.

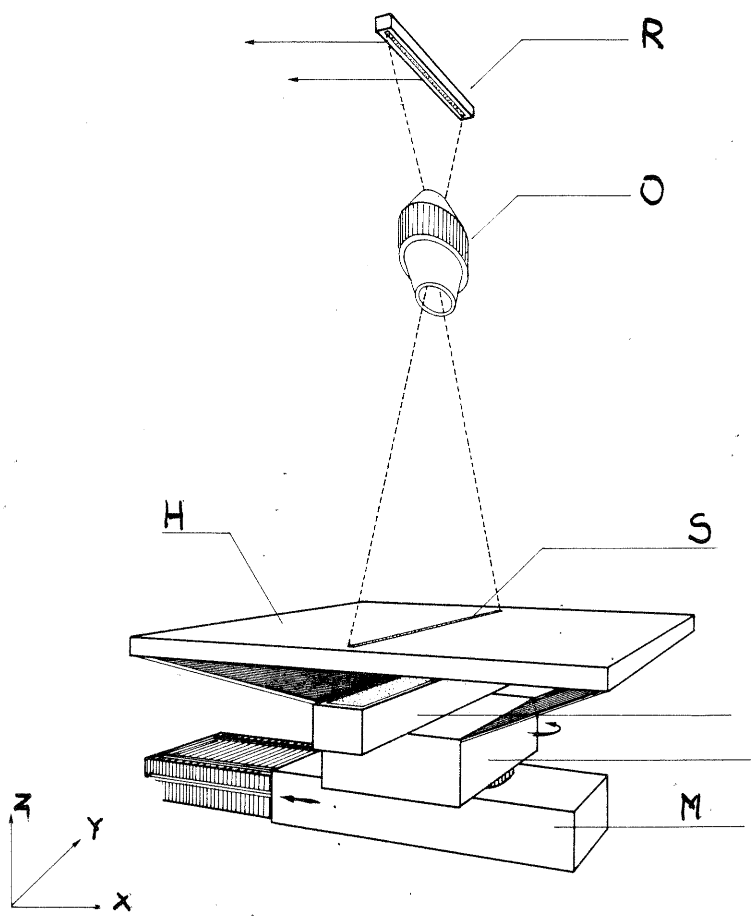


Fig.5: Sketch of the MFA-250-LS

In order to obtain a binary image, each element of the matrix must be assigned to one and only one of the two classes to be generated. For this reason we implemented an algorithm based on the examination and modification of the input matrix histogram.

Assuming that data are affected by a gaussian noise and that consequently the theoric histogram is composed of two partially overlapped gaussians (one relative to the noise itself and the other to the signal),the problem of determining the decision threshold can be dealt with two ways:

M1: the actual histogram is interpolated, the parameters - mean value and variance - of

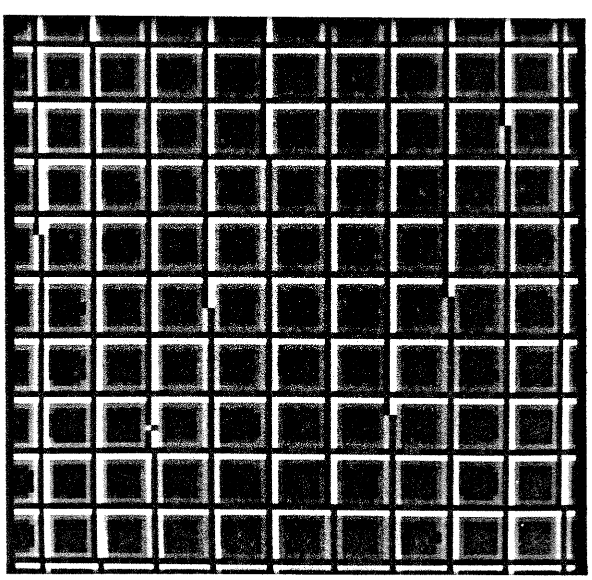


Fig.6: MFA-250-LS Microphotometer

MFA-250-LS FEATURES

Support	aero-photo
Reading Format, mm^2	205x205
Spatial Resolution,Pixel/Row	2048
Pixel Area, um^2	100x100
Positioning error, um	2
Orthogonality error, degrees	$5x10^{-4}$
Photometric Resolution,classes	256
Dinamic Range, decades	3

TABLE 1

the best gaussian functions are obtained and then the threhsold is detected as the minimum error point when a pixel is assigned to a class;

M2: in an interactive approach, by using graphic-pictorial devices for checking the selected threshold value.

6.2 Thinning Procedure

The result of P4 procedure is a binary image containing lines, which correspond to the reticle signs, and which have a variable width greater than one pixel.

In order to obtain lines which have a constant width of just one pixel, so that the detection of nodes is simpler, faster and more exact, the P5 procedure must be executed.

The P5 procedure returns a matrix, containing the medial axis of the lines, which is dimensionally equal to the input one. The thinning algorithm is then a transform operator, which does not topologically change the connectivity properties of the image, and at the same time, controls the width and the position of the computed lines.

The basic concept for the thinning process consists in removing, at subsequent iterations, certain points belonging to the boundary of the lines without modifying their connectivity.

The digital image is scanned top-down and left-right, during subsequent explorations, and the non-essential points are removed by extimating all the possible configurations between the examined pixel, centered to a 3x3 moving window, and its 8-neighbours.

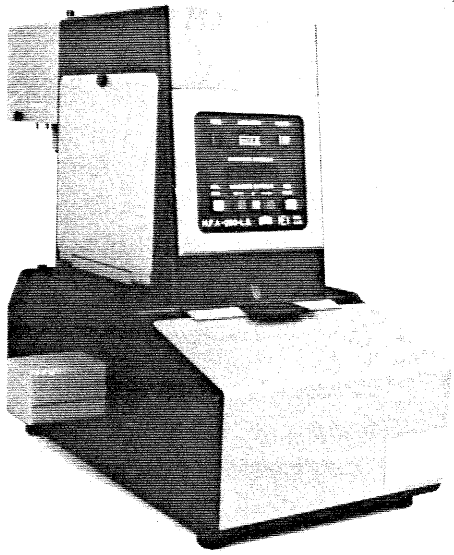
7. Conclusions

One test image has been digitized with the device and has been processed with the previously described preprocessing procedures.

In this experiment, instead of digitizing a photogram of the scene, we acquired the reticle itself. The reticle has lines whose width is 0.2 mm and spacing is 1 mm; the 512x512 digitized matrix has been processed by using firstly the P4 and then the P5 procedures. (5)

In fig.7 the input matrix is overlapped to the thinned matrix: we can see that the thinned reticle is entirely inside the width of the lines of the digitized reticle, so that the error in detecting the plane coordinates is quite defined by the resolution of the scanning device. In fig.8 a row of the fig.7 matrix is drawn: we can see that the thinned reticle (points with 0 value) is well centered in the thick lines of the input matrix.

If a smaller error is needed, a greater resolution device has to



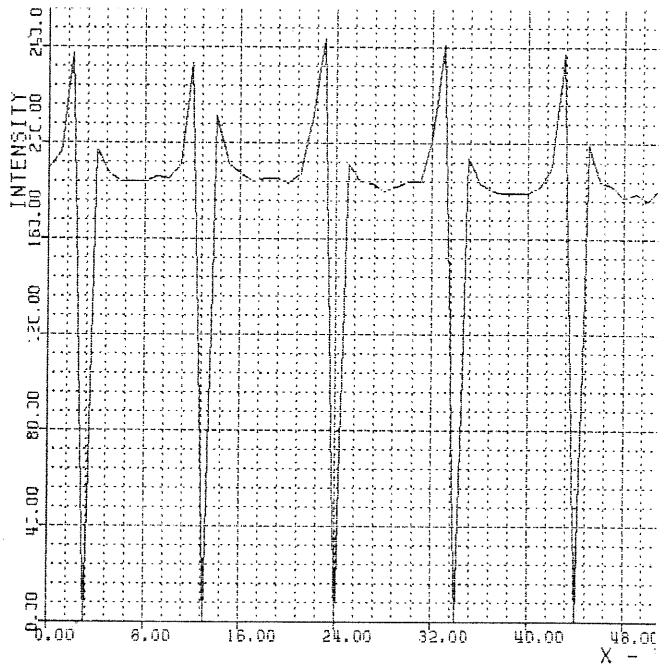


Fig.7: Output image(see text) Fig.8: Output image (see text)

be used; of course if the resolution increased N times, the amount of data increases NxN times and consequently a more powerful processing structure is needed if the efficiency has to remain the same. Thus the resolution must be chosen according to a careful evaluation of the precision to be obtained and of the performance to be gained.

In further tests, with a higher resolution image scanner (MFA-150-LS) we would be able to specify the precision of the photographic set (metric camera and projector, and reticles) and of the scanning device, to be used in operating procedures.

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