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APPLICATION OF DIGITAL IMAGE PROCESSING IN THE FIELD OF CLASSICAL PHOTOGRAMMETRY

تطبيق معالجة الصور الرقمية في المجال المساحة الفوتوجرامترية الكلاسيكية (الأرضية)

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الخلاصة - لقد حدث تطور كبير في مجال المساحة الفوتوجرامترية خاصة في استخدام المعالجة التحليلية لحل المشاكل المعقدة في هذا المجال .
أمكن في هذا البحث المعروض تأكيد امكانية واستعراض مرونة معالجة الصور الرقمية في مجال المساحة الفوتوجرامترية الكلاسيكية (الأرضية) والتي اقتصر استخدامها في الفترة الماضية في تطبيقات الاستشعار من بعد .
والبحث المعروض يعتبر اضافة جديدة في ابراز قوة ومرونة وأهمية المعالجة الرقمية في التطبيقات المختلفة في فروع المساحة الفوتوجرامترية .

ABSTRACT- Digital image processing in the field of conventional photogrammetry may use operational methods, which have been developed for remote sensing. Restoration of photographic imagery's resolution however, affords large data sets, which cannot be handled economically on today's computer generation. The flexibility of digital image processing is demonstrated for applications of terrestrial photogrammetry.

1. INTRODUCTION:

Progress in photogrammetry happened in the past in the field of analytical processing. The development of large digital computers in the sixties provided the tool for rigorous transformation of image coordinate into object coordinates. In analytical photogrammetry, the image itself serves primarily as a - very effective- coordinate memory. This means, however, a limitation of the large potential of photographi imagery.

Photointerpretation has always used the "semantic" information content of the imagery rather than the geomatric one. Development of remote sensing during the seventies, particularly development of digital scanners, led to original image information in digital form. Consequently, digital image processing methods were developed and applied to semantic information analysis from airborne and satelliteborne imagery. Here, the image is digitally processed at a whole, not only for specific coordinate as in analytical photogrammetry.

Digital image processing has not been invented by remote sensing. Theory and technology was developed by information theory, communication engineering and electronic engineering. Many disciplines have profound experience in digital image processing, without any relation to remote sensing. The general flexiblity of digital image processing makes it a tool even for applications in the field of classical photogrammetry. First results are available for rectification of cylinderical walls (BÄHR 1978 / 1 / and digital orthophoto production (KONECNY 1979/2/, SCHUHR 1980/8/.

***My greatest debt of grotitude is owing to Herrn Professor Dr. W. Kaiser, Deutsches Archäologisches Institut, Egypt, who gave the initial stimulus for this research and offered all the sort of help that made it possible.**

Today, digital processing of sampled conventional photogrammetric imagery cannot yet compete economically with analog procedures, like photographic rectification or digitally controlled orthophoto production (VOZIKIS 1979) / 9 /. The data rate, necessary to maintain the photographic resolution in the digital version, still is too large for been handled with the present generation of computers. There is, however, a permanent tendency towards declining computing costs, which will allow economical digital processing yet during this decade.

Main advantage of digital image processing compared to analog methods is the possibility of semantic image manipulation, like image enhancement and classification. Adequate software packages, devoloped for remote sensing applications, are available. Nevertheless, photographic image processing will ever play an important role in photogrammetry, but digital procedures extend the scale of powerful photogrammetric methods.

2. Sampling of photographic Imagery and Display of Digital Data.

For digital processing of data, which originally is collected in photographic form, digitization is necessary as a first step; finaly display of the processed digital data in photographic form is necessary for evaluating the result, according to Fig. 1. Each step in Fig. 1 corresponds to a linear system, for which properties have been throroughly investigated by system theory (see i.g. OPPENHEIM / SCHAQFER 1987/5/, PRATT 1987/6/, LÜKE 1979/4/). A photographic image represents a two - dimensional continuous signal which has to be sampled and quantified in order to allow discrete digital processing. For comparing analog and digital image processing, one has to answer the question

How has a photographic image to be sampled
and how has digital data to be displayed photographically
without any reduction of information (resolution) ?

Fig. 1: System Sequence for Digital Processing of Photographic Imagery

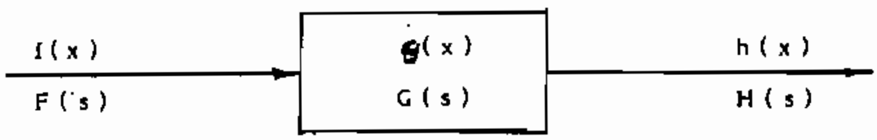


Fig. 2. : System Properties in Spatial and Frequency Domain

$$h(x) = f(x) * g(x) \qquad \ldots (1)$$

$$H(s) = F(s)\; G(s) \qquad \ldots (2)$$

$$h(x) = \int_{-\infty}^{+\infty} f(\tau)\; g(x-\tau)\, d\tau \qquad \ldots (3)$$

$$\mathcal{F}\{h(x)\} = H(s) = \int_{-\infty}^{+\infty} h(x)\, e^{-j2\pi sx}\, dx \qquad \ldots (4)$$

In system theory, signals are regarded both in the spatial and the frequency domain. Following Fig. 2, the input signal in the spatial domain is f (x), the impulse response g (x), and the output signal (result) h (x). In the frequency domain the parameters correspond to the input spectrum (F (s)) , the frequency response (G (s)), and the output spectrum (H (s)). The resulting output may be computed by the convolution integral in the spatial domain (Equ. (1), (3)) and by simple multiplication in the frequency domain (2). H (s) and h (x) are linked by the FOURIER-transform (4). FOURIER-transforms of several important functions are known a priori, i.g. for the rectangular pulse (Fig. 3a) and the Scha - function (Fig. 3b)

Photographic imagery represent band limited functions. According to Fig. 4 this means, that a frequency limit exist at $s = \nu$. Sampling of the corresponding spatial function f (x) can be analytically expressed by multiplying a Scha-function (Fig. 5). If the phase of the Scha-function is taken as

$$\tau \leq \frac{1}{2\nu} \quad , \qquad \ldots (5)$$

full resolution of f (x) is preserved (Fig. 5, right side). (5) is called the "sampling theorem".

Restoration of original F (s) from sampled G (s) may be done by isolation F (s) (Fig. 4, right side) in G (s), multiplying G (s) by a rectangular pulse of 2ν width (Fig. 6, Equ. (6), "Law pass filtering"). The original function in the spatial domain is obtained by the inverse FOURIER transform, applying the convolution theorem (PRATT P. 14/6/, LÜKE P. 22/4/) and the convolution integral (7). Finally, f (x) is represented by (8): the original function is restored from the sampled values f ($n\tau$), interpolating in between by "sinc" - functions sin $(2\pi\nu x - \tau) / (2\pi\nu x - \tau)$.

Consequently, digital processing of photographic imagery has to observe following conditions, if preservation of resolution is desired :

1. Sampling at a rate of $\tau \leq 1/(2\nu)$, where ν is the frequency limit of the photographic image
2. Display of the sampled picture elements, interpolating by sinc functions

Condition 1 may be observed by taking the appropriate sampling frequency, whereas interpolation by sinc-function would enormously expand the pixel number, so that it is practically not applied.

The sampling theorem demands digitization of two lines at least by 2 pixels, if proper interpolation is executed later on. As sampling is direction - depending and interpolation left out, sampling has to be done at higher rate. In practice,

$$\tau - 1/(3\nu) \qquad \ldots (9)$$

is taken as an appropriate value (see KONECNY / BÄHR / REIL / SCHREIBER 1979/3/.). The factor of 3 affects largely the economical considerations of digital versus analog image processing

3. Geometrical Model

In photogrammetry, geometrical models describe the relation between image coordinates and object coordinates. For digital image processing, the entire original image has to be converted according to the specific task. This geometrical transformation is absolutely free from limitations and obeys only the mathematical formulation

$$(X, Y, Z)_{Object} = F(x', y')_{Image} \qquad \ldots (10)$$

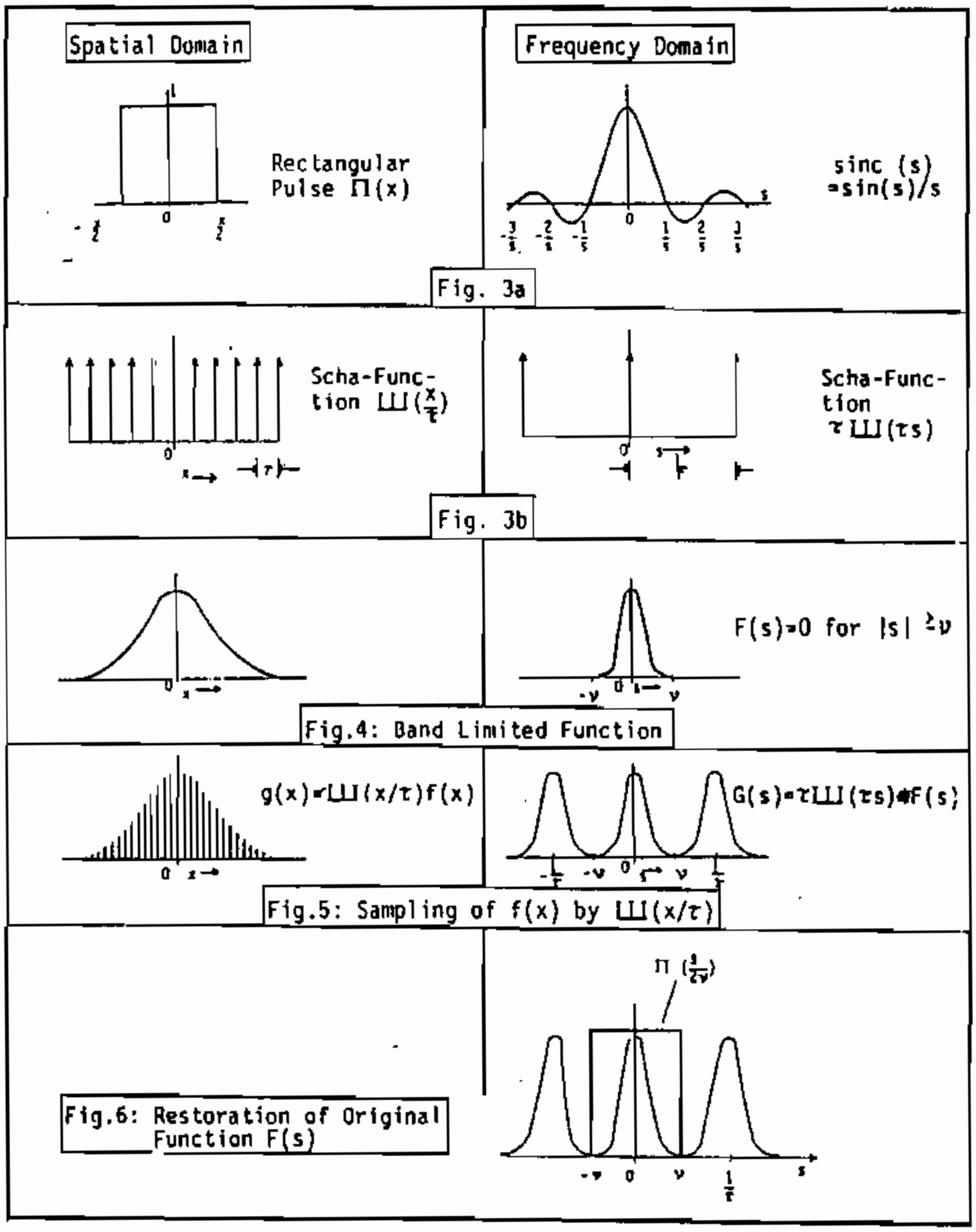


Fig. 3a

Fig. 3b

Fig.4: Band Limited Function

Fig.5: Sampling of f(x) by Ш(x/τ)

Fig.6: Restoration of Original Function F(s)

$$F(s) = G(s)\ \Pi\left(\frac{s}{2\nu}\right) \qquad (6)$$

$$f(x) = \mathcal{F}^{-1}\left\{G(s)\ \Pi\left(\frac{s}{2\nu}\right)\right\} = g(x) * \frac{\sin(2\pi\nu x)}{2\pi\nu x} = \int_{-\infty}^{+\infty} g(x)\ \frac{\sin(2\pi\nu\, x-\tau)}{(2\pi\nu\, x-\tau)}\, d\tau \qquad (7)$$

$$f(x) = \sum_{n=-\infty}^{n=+\infty} f(n\tau)\ \frac{\sin(2\pi\nu\, x-\tau)}{(2\pi\nu\, x-\tau)}\, d\tau \qquad (8)$$

consequently, digital image processing offers more geometrical flexibility than analog photographic processing. The advantages are obvious for processing of "non-conventional" imagery; they have however been shown for conventional photogrammetric imagery, too (see BÄHR 1978/1/ , KONECNY 1979/2/.

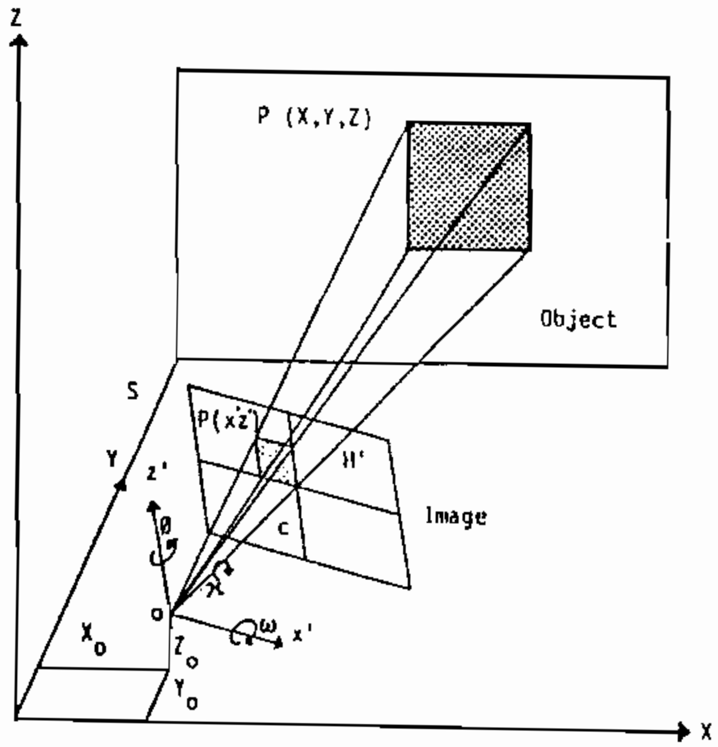


Fig. 7: Geometrical Model for Processing of Terrestrial Imagery

we restrict the geometrical transformation to linear processing of plane object. Fig. 7 specifies the conditions for this case. The object plane is parallel to the X/Y - plane, at a distance of S. The exterior orientation of the image is described by X_o, Y_o, Z_o and ϕ , ω , k. An object Point $P(X, Y, Z)_i$ may be written by the collinearity equations

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_i = \lambda \cdot \underline{\underline{D}}_{\phi,\,\omega,\,k} \begin{bmatrix} x' \\ c \\ z' \end{bmatrix}_i + \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} , \quad \ldots (11)$$

where λ is a scale factor and $D_{\phi,\,\omega,\,k}$ the orientation matrix

$$\underline{\underline{D}}_{\phi,\omega,k} = \begin{bmatrix} \underset{(a_1)}{\cos k \cos\phi - \sin k \sin\omega \sin\phi} & \underset{(a_2)}{\cos k \sin\phi + \sin k \sin\omega \cos\phi} & \underset{(a_3)}{\sin k \cos\omega} \\ \underset{(b_1)}{-\cos\omega \sin\phi} & \underset{(b_2)}{\cos\omega \cos\phi} & \underset{(b_3)}{\sin\omega} \\ \underset{(c_1)}{\sin k \cos\phi + \cos k \sin\omega \sin\phi} & \underset{(c_2)}{\sin k \sin\phi - \cos k \sin\omega \cos\phi} & \underset{(c_3)}{\cos k \cos\omega} \end{bmatrix} \quad \ldots (12)$$

After shifting O into the origin of the X/Y/Z - system and modificating equation (11) we obtain the object coordinates X, Z as a function of image coordinates x' , z' according to (10) :

$$X = S \frac{a_1 x' + a_2 c + a_3 z'}{b_1 x' + b_2 c + b_3 z'}$$

$$Z = S \frac{c_1 x' + c_2 c + c_3 z'}{b_1 x' + b_2 c + b_3 z'} \qquad \ldots (13)$$

$$Y = S = \text{constant}$$

An image display of the object has to use a scale factor, which may be set by manipulating S. If the object shall not be displayed in the X/Z - plane, the coordinates (13) have to be changed digitally taking

$$(\bar{X}, \bar{Y}, \bar{Z}) = G\,(X, Y, Z) \qquad \ldots (14)$$

which allows e.g. transformation of perspective center and viewing angle as well as distortion of the object surface itself (unrolling a cylinderical facade: BÄHR 1978/1/ ; flattening of a globe: YOZIKIS 1979/9/.)

From (13) the parameters $a_1 \ldots\ldots c_3$ may be determined by least squares adjustment, taking control points in the object system X, Y, Z if the orientation is not known a priori.

4. Geometrical Rectification

Once the orientation parameters are known, a geometrical rectification is possible by an ordinary rectifyer, introducing ϕ, ω, k directly. However, the instrumental scale is limited, for a ZEISS SEG V approximately at $\phi = \omega = 6°$, consequently the rectification can there only be generated by multiple processes.

Digital rectification allows a straight forward approach, supposing digitized data. Presently, processing large amount of picture elements ("pixels") still leads to severe computing problems, which will be overcome in the near future by new generations of computers. After digitization of the photographic image observing the sampling theorem, digital rectification is recommended to be executed by the "indirect" method, explained by Fig. 8: Taking the regular pixel pattern of the rectified image, appertaining pixel coordinates in the distorted image are computed by (13), and their interpolated grey values are transferred.

If the geometric distortions and pixel number are large, rectification has to be done by segments (Fig. 8: 1 a, b, c, d) in order to maintain

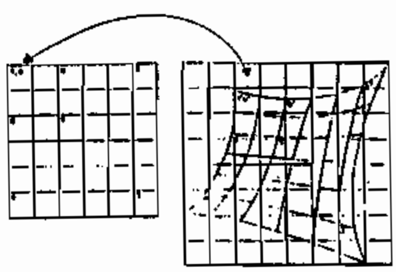


Fig. 8: Digital Geometrical Processing; Indirect Method

reasonable computing time. One segment has to fill the computer's core momory, avoiding time consuming frequent access to peripherel storage media.

Note:

Rectification accuracy is established by the geometrical model

Rectification economy is established by the rectification procedure.

5. Results from Digital Processing of Photogrammetric Imagery

Object of practical investigation were a building of the white House, Faculty of Engineering, El-Mansoura University (Fig. 10 a). In order to keep computing time short, sampling of the original imagery (UMK JENA 13/18, c = 100 mm) was done by 100 μm x 100 μm pixel size (OPTRONIC machine) of the Deutche Archilogic Institute, Egypt). Resolution of the photography was determined by the sector stars of the test target, which demonstrated a resolution of 33 Linepairs/mm of the original material.

The original images have a format of 120 mm by 160 mm. This leads to $1{,}9 \cdot 10^6$ pixels for 100 μm sampling. Correct sampling of 3 pixels per linepair affords a pixel size of 1/ (33.3) mm = 10 μm, resulting in $190 \cdot 10^6$ pixels altogether. This number can hardly be handled with computers available today.

Object	ϕ^g	ω^g	κ^g	Pixel Number Original	Pixel Number Original	Sections	Computing Time (sec)
White Hause Building	0	33	0	$2{,}25 \cdot 10^6$	$1{,}70 \cdot 10^6$	12 8 7	62,7 53,7 44,0
White Hause Building (Fig. 10)	23	33	0	$2{,}19 \cdot 10^6$	$1{,}75 \cdot 10^6$	8	46,2
Test Target (Fig. 11)	38,5	40,1	-2,7	$2{,}62 \cdot 10^6$	$1.50 \cdot 10^6$	8 6 3	51,9 45,1 33,6

Table 1: Results of different approaches for geometrical rectification

Table 1 Lists the results obtained from digital rectification of the images. For the white House building, two different photos were evaluated, one with $\phi = 23^g$ (Fig. 10), another with $\phi = 0^g$. The computing time depends very much on the number of sections formed, i.e. of the efficient use of the available core memory. The computing time is in correspondance with the values for digital rectification of a cylinderical facade (BÄHR 1978/1/).

The quality of the resulting rectified imagery is very much affected by poor resolution because of "undersampling", by the factor of 10, which yields resolution of only 3,3 linepairs per millimeter. This effect is much more obvious for the test target than for the While Hause building. In order to visualize the undersampling effects, Fig. 12 shows parts of Fig. 11, enlarged by the factor of 5.

The examples (Fig.10 b, 11 b) demonstrate, however, that digital rectification is principally possible. The orientation parameters ϕ, ω , k have been determined in situ by a theodolite for the White Hause building, whereas they were computed by analytical space intersection for the test target. Remaining distortion of horizontal lineas at the upper part of the test target are already in the original photography (Fig.11 a), due to distortion of the target plate.

The actual advantages of digital image processing versus analog procedures are in the "semantic"- field, as stated above. Fig. 14 shows two examples for digital manipulation of the image content. The histogram of a rectified image (for ϕ=0 not shown) is displayed in Fig. 13. The main information of the building itself lies between the grey values 80 and 180. Fig 14 a shows the image after transformation of the original grey values G into G' :

$$0 \leq G \leq 80 \quad : \quad G' = 0$$
$$80 \leq G \leq 180 \quad : 0 \leq G' \leq 255 \text{ (linearization)}$$
$$180 \leq G \leq 255 \quad : \quad G' = 255$$

This manipulation results in an image with much higher contrast than the original one, which would not have been available by analog photographic means.

Fig.14 b finally demonstrates a line extraction effect. To keep noise low, a moving average was formed (original) image $\phi = 0^g$) with following histogram processing.

REFERENCES:

1- BÄHR, H.P. : Digital Rectication of a Facade ISP Commission III Symposium, Moscow 1978.

2- KONECNY, G. : Methods and Possibilities for Digital Differential Rectification. Photogrammetric Enineering 1979. S. 727.

3- KONECNY, G. : Einsatz photogrammetrischer Kameras aus dem Weltraum für kortographische Anwendungen. Veroff. des Instituts für photogrammetric, Heft SCHREIBER, H.C 4, Hannaver 1979.

4- LÜKE, H.D. : Signalübertragung. Berlin, Heidelberg, New York 1979.

5- OPPENHEIM, A. V. : Digital Signal Processing. Englewood cliffs 1975.

6- PRATT, W. K. : Digital Processing. NEw York, Chichester, Brisbane, Toronto, 1978.

7- ROSENFELD, A. : Digital Picture Analysis. New York 1976.

8- SCHUHR, W. : Analysis and Application of Algorithm for Digital Orthophotos. ISP Congress Hamhurg 1980.

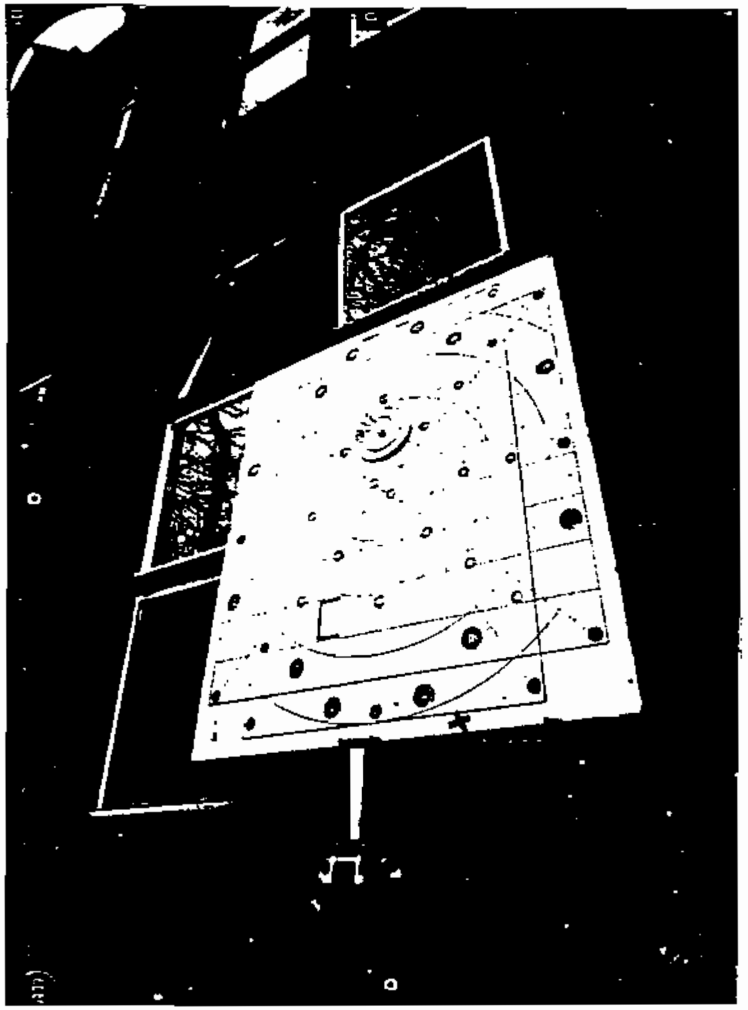
9- VOZIKIS, E. : Die photographische Differentialumbildung gekrümmter flächen mit Beispielen aus der Architekturbildmessung. Geowissenschaftliche Mitteilungen, Heft 17, Wien 1979.

Fig. 10 a: Faculty of Engineering (White Hause), Original UMK

$\varphi = 23^9$, $= 33^9$, $k = 0^9$

Fig. 10 b: Faculty of Engineering (White Hause), Digital Rectific.

⊢—⊣ Corresponds to 2 m.



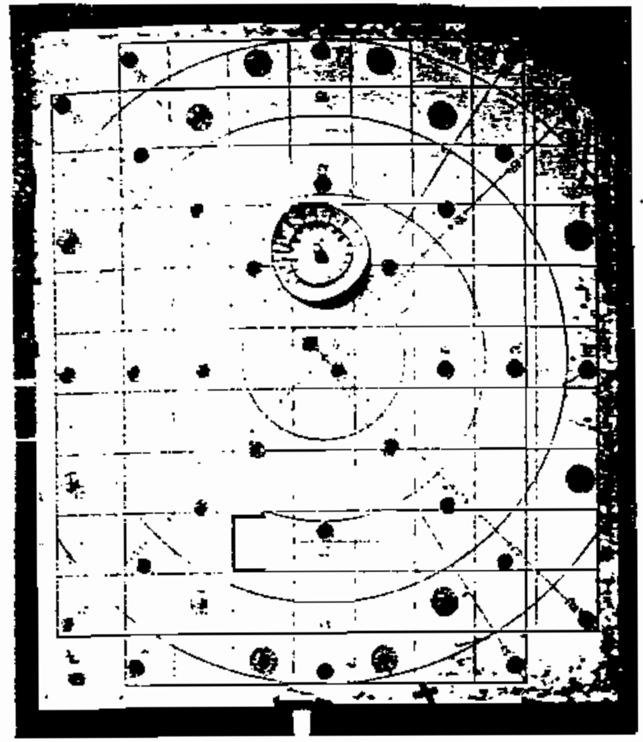
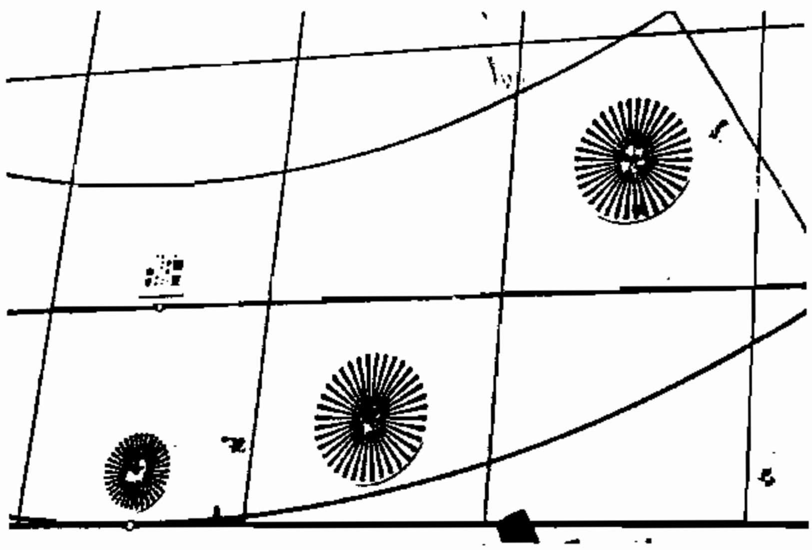
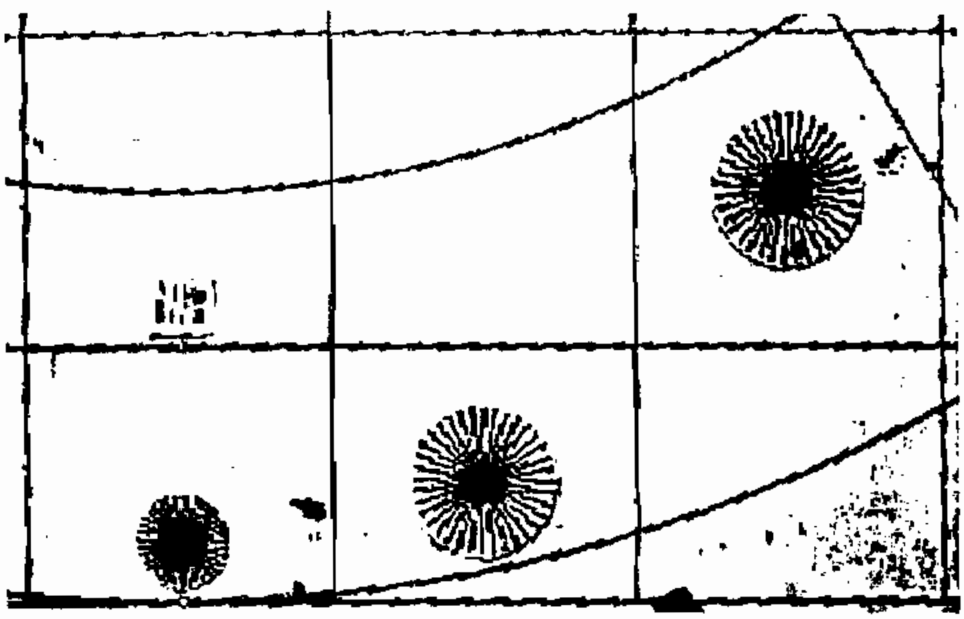


Fig. 11b (above): Test Target, Digital Rectification
I Quadrat Corresponds to 15 cm x 15 cm in Object

Fig. 11a (left): Test Target, Original UMK Image
$\phi = 83{,}5^g$, $\omega = 47{,}1^g$, $\kappa = -2.7^g$



a



b

Fig. 12: Enlarged Sections from Fig. 11 (Factor of 5)
1 Quadrat Corresponds to 15 cm x 15 cm in the Object

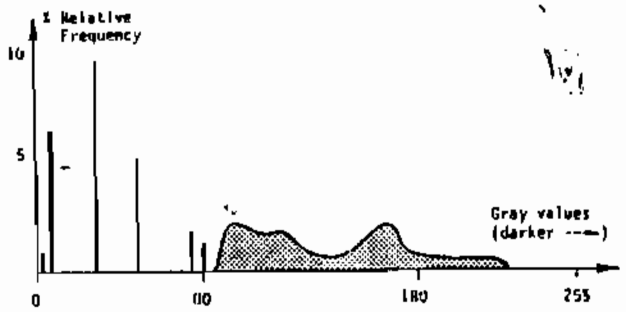


Fig. 13:
Original Histogram

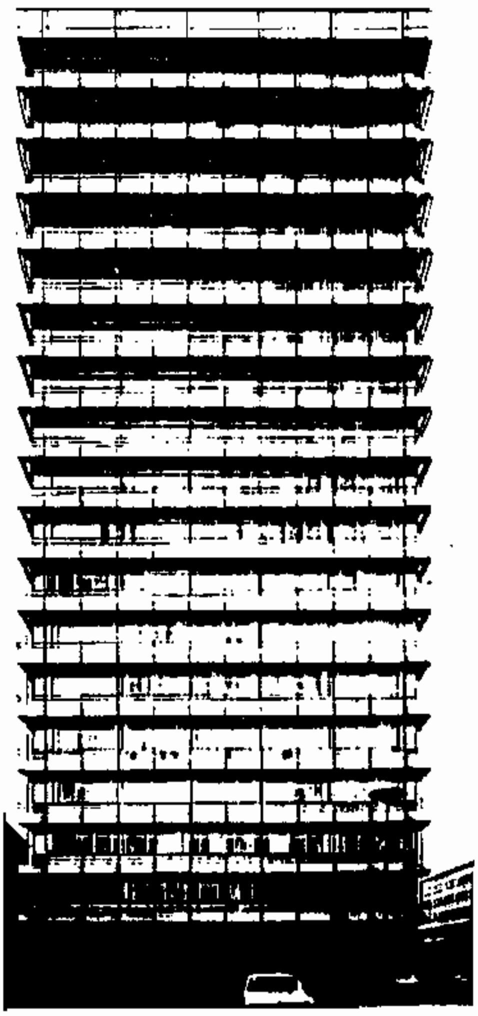


Fig. 14a : Histogrammanipulation

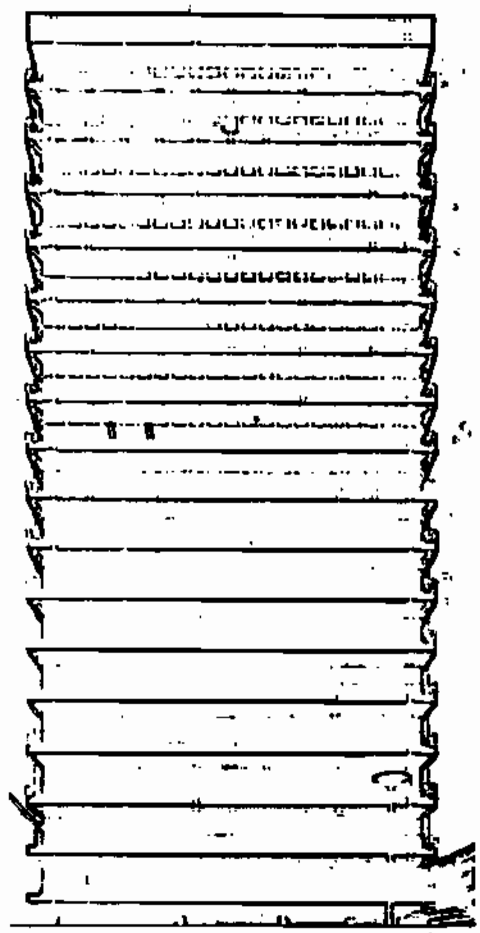


Fig. 14b : Line Extraction