AUTOMATIC POINT DETERMINATION IN A RÈSEAU-SCANNING SYSTEM

Thomas Luhmann
Institut für Photogrammetrie
und Ingenieurvermessungen
Universität Hannover
West-Germany

ABSTRACT

Automatic extraction and measurement of marked points is an important task in digital photogrammetric applications. For that purpose an advanced system for pattern recognition and precise point determination is presented. It is used for target location and control in the réseau-scanning systems, which offer digital recording of analogous photographs as well as on-line measurements in the field.

ZUSAMMENFASSUNG

Digitale photogrammetrische Anwendungen erfordern automatische Verfahren zur Erkennung und Messung signalisierter Punkte. Dazu wird ein System zur Mustererkennung und präzisen Punktbestimmung vorgestellt. Es wird zur Punkterkennung und Steuerung réseau-abtastender Systeme eingesetzt, sowohl bei der Digitalisierung analoger Vorlagen als auch bei der On-line-Aufnahme vor Ort.

INTRODUCTION

Digital photogrammetric methods offer a large variety of applications in close-range photogrammetry with on-line and real-time systems being developed in recent research projects. In addition to necessry hardware devices, robust and precise geometric image processing methods are required, which enable an extraction of image information such as points, lines and edges.

This task can be simplified by well-defined marked signals projected in the image. In the field of industrial photogrammetry the preparation of type and distribution of marked points just can be optimized, so that that the following point measurement is performed almost automatically. On the other hand those signals are affected by unforeseen distortions like rotation, deformation and shading. The determination of image reference points (fiducial marks, réseau crosses) can be figured out comparable to the detection of marked points.

Several point-determination methods reaching subpixel-accuracy are known, of which the suitability is depending on the type of signal. These procedures all are characterized by algorithms including picture elements of a larger point neighbourhood and leading to precise point determination by adjustment or interpolation techniques.

In the following chapters a system for automatic point determination is presented, which consists of the new Rolleimetric RS1 (LUHMANN and WESTER-EBBINGHAUS 1986) and a modular software system for scanner control and point detection. After a short introduction to the réseau-scanning imaging system concept and procedures of the software system are shown.

RÈSEAU-SCANNING IMAGING SYSTEM ROLLEIMETRIC RS1

CCD-matrix sensors are suitable for digital image recording, used in on-line digital measurements or A/D-conversion of analogous photographs.

The image size of common matrix sensors is less than 100 mm^2, which is too small to achieve sufficient image scale. Larger image formats can be recorded by sensor formations simultaneously or step by step, if single sensors can be orientated in the image space (ALBERTZ 1986, BROWN and FRASER 1986, WESTER-EBBINGHAUS 1984).

While the system concepts of ALBERTZ as well as BROWN and FRASER require instruments of high geometric stability, the principle of réseau-scanning technique by WESTER-EBBINGHAUS allows optical-numerical sensor orientation at any time of recording. Based on this idea the new réseau-scanner Rolleimetric RS1 was developed and just presented (LUHMANN and WESTER-EBBINGHAUS 1986).

The RS1 can be used as a digital mono-comparator ensuring both, high resolution and geometric precision. Fig.1 shows the RS1 and the personal computer system for scanner control and image processing.

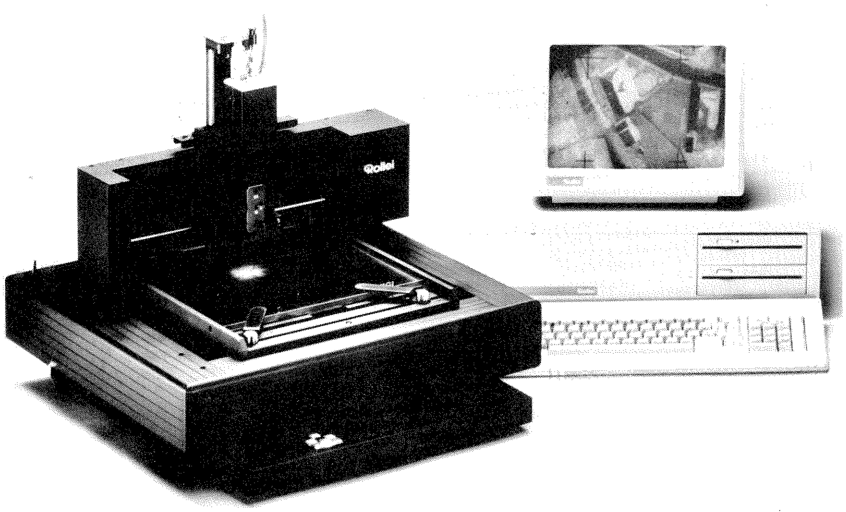

Fig.1 Réseau-scanner Rolleimetric RS1

The RS1 allows digitizing of aerial photographs (230 x 230 mm) with a minimum pixel size of 2.5 x 3.9 µm.

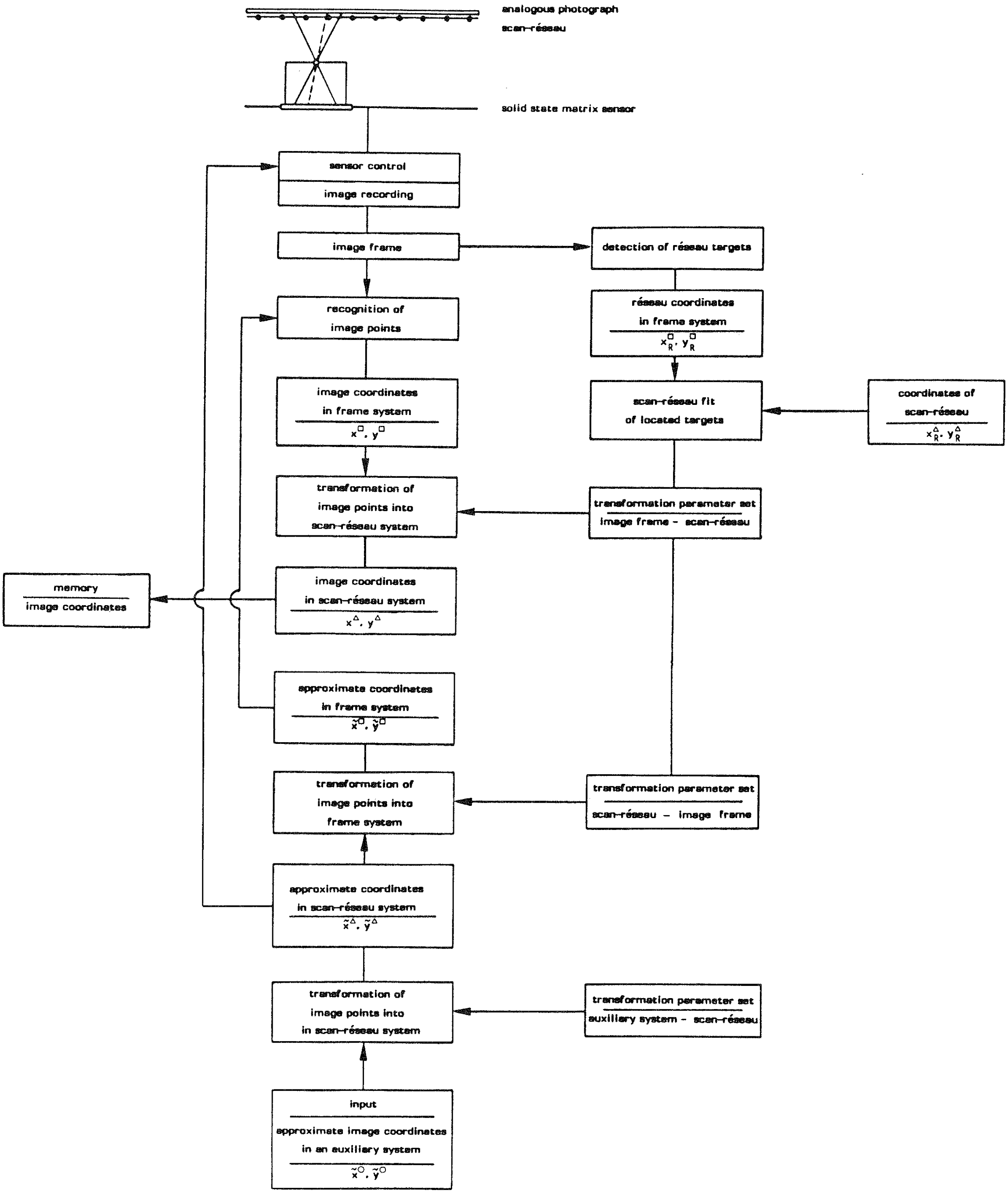

Fig.2 Principle of réseau-scanner used as automatic mono-comparator (WESTER-EBBINGHAUS 1986)

Fig.2 shows the principle of scanner operation. Input of initial values by an auxiliary system (graphics tablet) moves the matrix sensor to the specified réseau grid. Now the process of automatic optical-numerical sensor orientation leads to a parameter set for transformation of image frame coordinates into the scan-réseau system. Furthermore approximate coordinates of points to measure can be transformed into the image frame system and are supporting automatic point detection as discussed below.

Further concepts and operation modes of réseau-scanning devices such as stereo and multi-image recording are presented by WESTER-EBBINGHAUS (1986).

AUTOMATIC POINT DETERMINATION

System configuration

Fig.3 shows the essential components of a system for automatic feature extraction and point determination to use in a photogrammetric mono-image recording system.

Image recording is performed by a CCD-matrix sensor, which is a module in a réseau-scanning imaging system. After A/D-conversion the digital image is stored in a direct access frame memory.

The human operator selects the type of pattern to detect, which has to be stored in the pattern base. Suitable measuring procedures are registered in the method base and were also selected by operator. Due to the selected pattern type and determination method the system generates a synthetical reference pattern or a structural description. Synthetical images can be created in the simulation module, while structural description (e.g. center of cross target = intersection point of two straight lines) are generated in the program selected from the method base.

In the step of pattern recognition the image is searched for the signal and its coordinates are stored, if the pattern is detected. These coordinates are used as initial values for the following precise point determination. At the moment, procedures for detection of cross targets and spots in binary images are implemented.

Alternatively, approximate values can be defined on a video display (trackball), entered by a graphics tablet or calculated by an existing orientation parameter set.

The human operator sets the point number to give a definite point identification. The precise point determination is then performed by the selected procedure stored in the method base. The resulting image coordinates are registered for following evaluations.

The system is characterized by high flexibility and supplies point determination methods of highest accuracy. Suggestive and practicable application of the program modules is controlled by the operator. For instance, it is often easier and faster to enter approximate values by an auxiliary system than to search a total image for a specified signal.

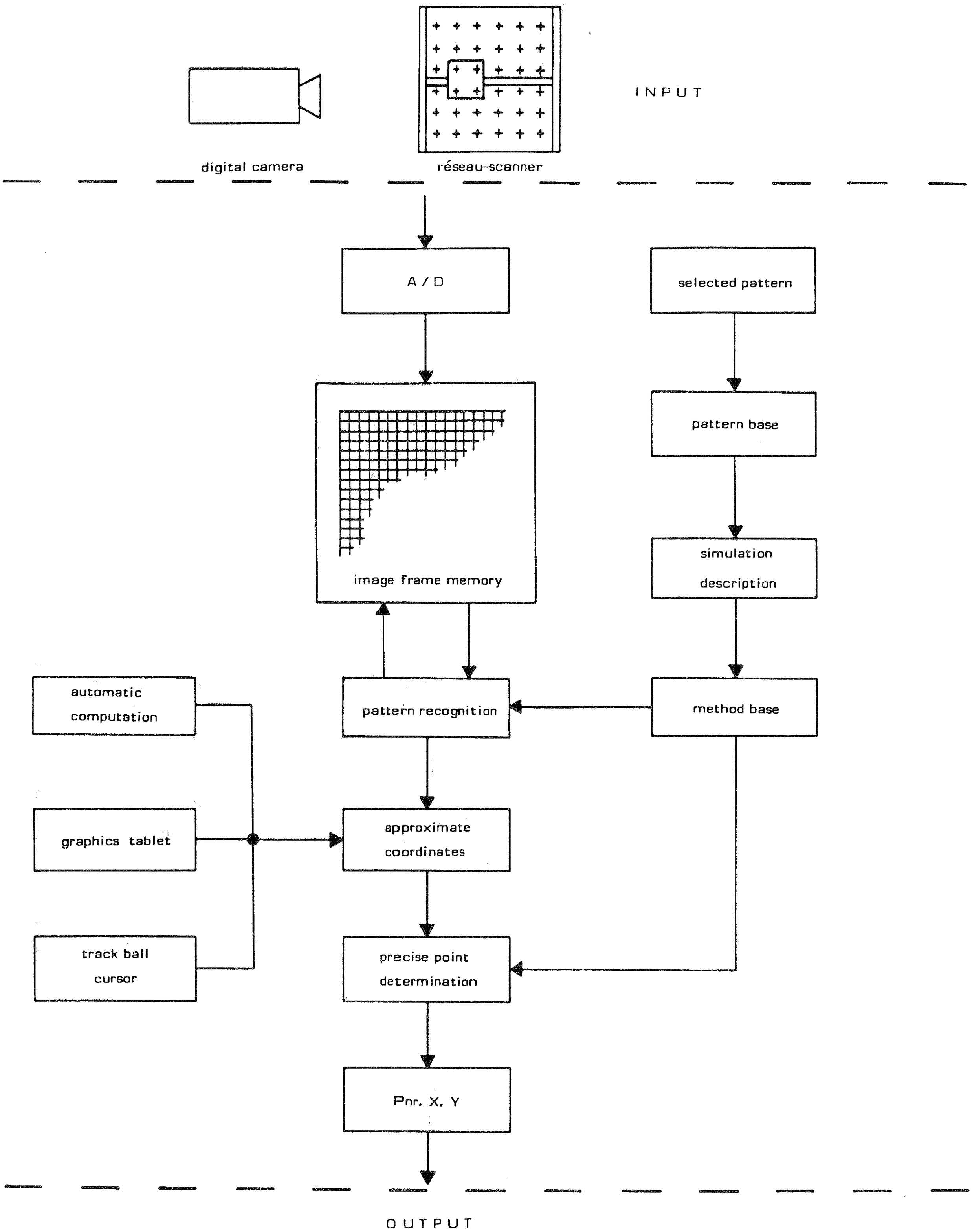

Fig.3 A system for automatic pattern recognition and point determination

Procedures for precise point determination

At the moment following precise point determination methods leading to subpixel-accuracy are implemented in the system:

Spot-like patterns can be determined by
- computing the center of gravity
- least square fit of two-dimensional polynomials
- correlation techniques using synthetical reference images

Cross-shaped targets can be determined by
- the ring-operator (LUHMANN 1986)
- correlation techniques using synthetical reference images

Ring-shaped points can be calculated by an analysis of edges and determination of a least square fitted ellipse.

Furthermore the ring-operator is suitable for line following algorithms (LUHMANN et al 1986).

Due to the importance of line and edge elements used in photogrammetric signals the next chapter deals with the analysis of such patterns and derivation of the point's center with subpixel-accuray.

ANALYSIS OF LINES AND EDGES

Marked points are often used in close-range photogrammetry, because evaluation of single points is predominant and because well-defined signals offer highest accuracy in point measurement.

Cross-shaped targets are not only measurable with high precision in analogous and analytical photogrammetric instruments, but they also have suitable attributes for digital point determination due to their textured line features.

Therefore a short survey of point determination methods using line and edge extraction is following.

Line and edge elements are located in those parts of the image, where the intensity function has steep gradients in one direction. In spatial domain various filter functions can be designed to approximate first derivations (lines) and second derivations (edges) (DAVIS 1975). Convolution and zero-crossing detection combined with a one-dimensional polynomial fit leads to edge and line extraction with subpixel-accuracy (FROBIN und HIERHOLZER 1983).

Fig.4 shows the principle of an advanced method for rotation-invariant detection and classification of line elements of a cross-shaped target (LUHMANN 1986).

Given the approximate value of target center P_0 , various concentric intensity function rings r_i, $r_E \geqslant r_i \geqslant r_A$ are created.

Then the two-dimensional image function is transformed into one-dimensional vectors of length $u_i = 2\pi r_i$ by bilinear interpolation methods. Herein fast convolution and line detection is computed. Line points **S** relating to one leg of the target are combined in a least square polynomial fit **F.** Then the point of polynomial intersection can be calculated to obtain the displacement vector $\underline{d}$ with high accuracy.

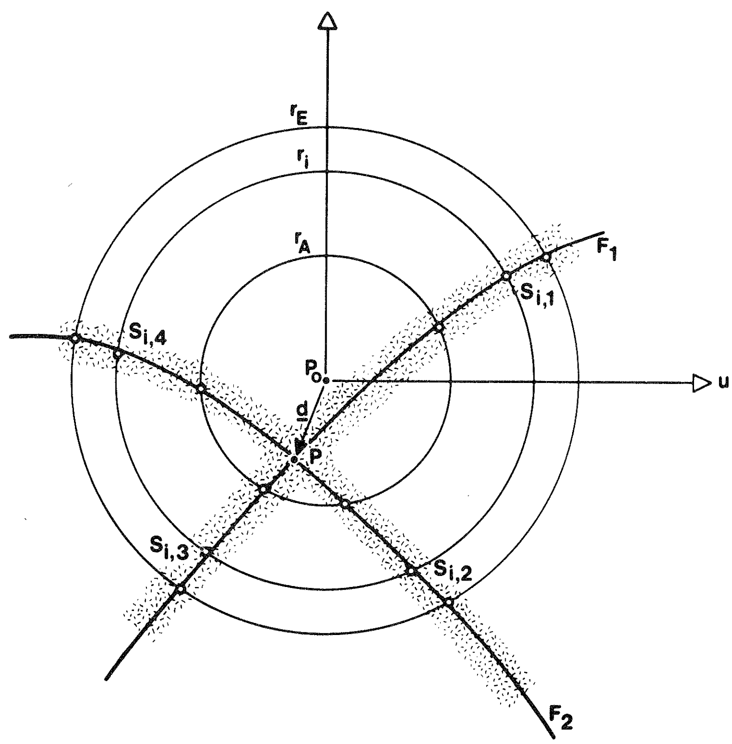

Fig.4 Rotation invariant location of cross-shaped targets

Moreover the operator computes some special features for each line point:
- arc length (directional information)
- amplitude and sign of zero-crossing (convolution output = textural information),

which can easily be used to classify line points and to generate a numerical geometric and textural description of the target.

Ring-shaped structures can be detected by an inverse mode of this operator (Fig.5). Again, given the approximate value of center P_0, radial straight lines of intensity vectors are created. These one-dimensional vectors are used for detection of suitable line points in the same manner as figured out for the ring-operator. Then a least square fit of line points leads to the center of an ellipse, which yields to the displacement vector $\underline{d}$.

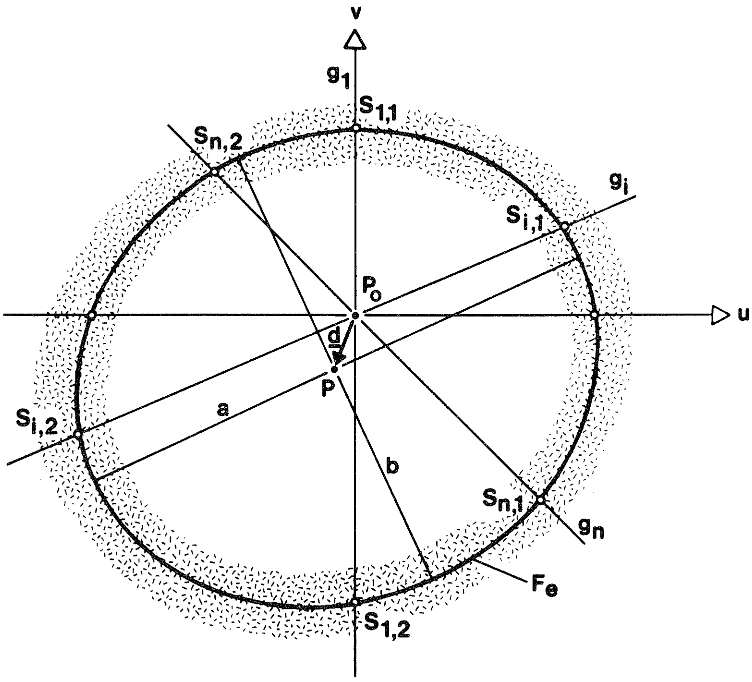

Fig.5 Location of ring-shaped targets

Both methods result in a precise point determination using a combination of least square fitted curves. Not only high accuracy but also a parameter set of inner accuracy (standard error of unit weight) and geometry (coefficients of polynomials) is obtained, which can be very important for evaluations such as automatic point identification or correspondence of images.

RESULTS AND CONCLUSION

Fig.6 shows some enlarged details of photogrammetric images. Cross-shaped targets, segment points and spot-like points seem to be very useful signals for automatic digital measurements and can be located by the presented hard- and software devices with high precision.

The inner accuracy of point measurements using precise detection methods amounts to 0.1 - 0.2 pixel. For instance, if a scan-réseau of 2mm grid size is mounted in the RS1 an accuracy of 1 micron can be obtained for optimal detectable marked points.

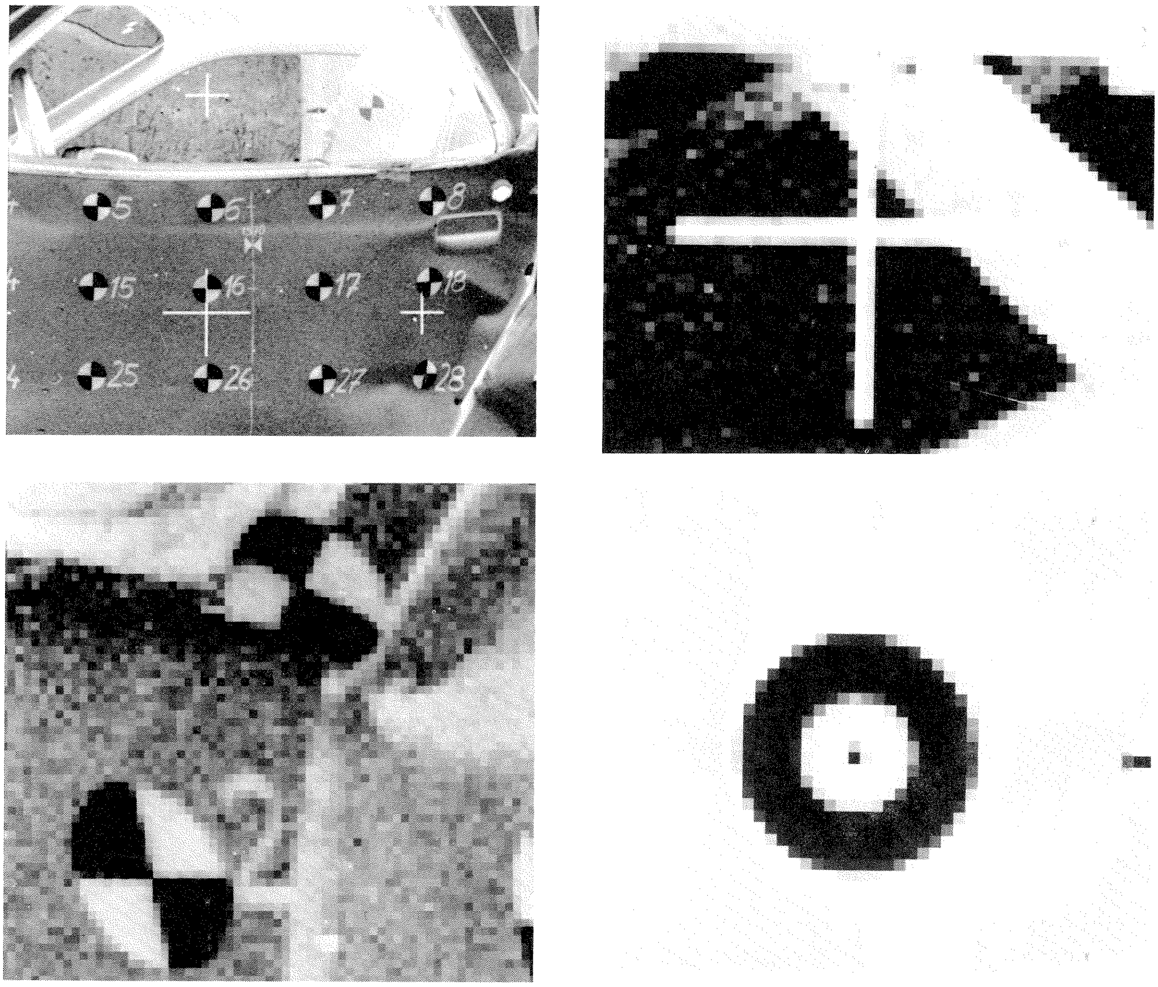

Fig.6 Marked points in digitized photogrammetric images

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