MIROS

A new software for Rollei RS1 digital monocomparator

Martin Knobloch, Torsten Rosenthal
Institut für Robotik und Prozeßinformatik
Technische Universität Braunschweig, D-3300 Braunschweig

Commission V

PURPOSE:

A new powerful software for Rollei RS1 - digital monocomparator has been developed with the experience and knowledge gained during the past five years of practical use of the Rollei RS1.
Now, one software package is capable of measuring different signalazation types and can be used for different Réseau Cameras in particular for all the different Réseau Cameras manufactured by Rollei Fototechnic.
With the new advanced software program, the measurement procedure is fully automatic and codes for point numbers can be recognised. Individual measurement tasks are programmable with an integrated interpreter by the user.

KEY WORDS: Rollei RS1, Réseau, image processing, interpreter, ellipse, signal identification

INTRODUCTION

In cooperation with the Institute for "Robotik und Prozeßinformatik" and the Institute of "Photogrammetrie und Bildverarbeitung" of the Technical University Braunschweig, as well as the company Rollei Fototechnic, a new software for digital image evaluation with the Rollei Réseau Scanner RS1 was developed in a semester paper.

The system is based on the technique for réseau measurement, developed by Prof. Dr. Wester-Ebbinghaus, and on the experiences made with the Scanner RS1 and the corresponding software.

In the meantime, MIROS has become a very flexible program which makes possible to measure fully automatically ellipse point markings in negatives. Any format, including the LFC camera format can be measured with this program. Also the choice of the réseau dimensions is unrestricted, meaning that it can be measured in negatives either with or without illuminated réseau.

Due to this flexibility, it was made possible to measure in the new format of the Rolleiflex 6008 metric [GS 92]. An interpreter was integrated into the system to enable the user to structure his own program run easily. This interpreter allows the experienced user to write own measurement programs which makes exterior program interferences redundant. For standard applications, suitable interpreter files can be generated via existing program generators. A further significant capacity feature is the automatic adaptation to different negative illuminations through the scanner illumination regulation. To assure a perfect control, a distance op-timisation to receive minimal distances between the points is effected which keeps at the same time illumination differences on a minimum. This fact together with parallising the measurement via sensor movements reduced the measurement time remarkably. In recent tests, 300 signals were measured in only 7 minutes which corresponds to a measurement time of 1.4 seconds per point. One reason for this high speed must be seen in the ellipse measurement which is adapted to special situations.

A further acceleration was achieved with a highly mechanised image orientation. In most cases, it is now sufficient to give only on cross / mesh of the image to be able to determine the position of the image. A distinctive feature of ellipse measurement is the automatic point number identification. This was achieved by segment codes which were perfectly identified in first tests. In special cases, it is nevertheless still necessary to measure points manually by using the cursor. This measurement technique is as well supported by MIROS and is extended by the possibility to adjust the cursor also in the sub pixel area. The underlying Algorithms will be analysed in the following chapters.

INTRODUCTION IN THE SYSTEM

Measurement Setting

For running the MIROS measurement program, any DOS - computer of the 80x86 series is sufficient, which needs to be equipped with a numeric coprocessor.

To work with the digital partial images, two different frame grabbers can be used at present. Those are the FG 100 image card and the newer version, the VFG 100 of Image technologies.

The system is completed with the RS1 Scanner of Rollei Fototechnic (Figure 1) This scanner makes possible to work with negatives of a format up to 23 x 23 cm and is being updated at present to achieve a further reduction of the movement intervals from point to point.
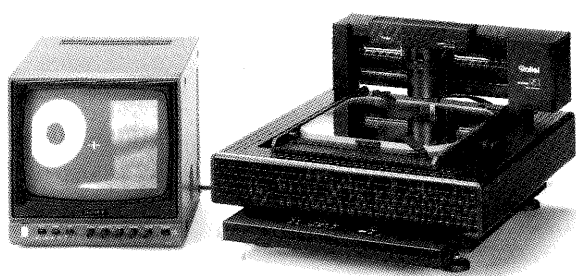

Figure 1: Réseauscanner RS1 with monitor

Basic Principals of the Réseau Measurement Technique

Its task is to give an exact identification of the position of ellipse points with high accuracy. This is achieved by moving a sensor over the image which is able to take up partial image of 5 square mm in which the signals are measured later on. The position of the digital partial image cannot be determined by the actual position of the sensor as one would presume. This would mean that the positioning accuracy of the scanner would determine the measurement accuracy. For that reason the position is determined by the réseau orientation. For this purpose, either a glass plate with réseau crosses is fixed directly above the negative or such a grid is placed directly in the negative illumination. The position of the sensor can only be determined when four crosses (mesh) are measured in the digital partial image and the accuracy of the scanner is only relevant for approaching the meshes (DR 91 and GP 88).

MEASUREMENT PREPARATION

Initiating the Mesh System

The first step when measuring in image negatives is to adjust the scanner so that the information from the negative is accurate and well illuminated. The user has the opportunity to move the sensor in vertical direction to reach perfect focusing. Alternatively, the system is able to adjust automatically. This is based on the principle to reach highest gradients with occurring margins and therefore, the adjustment received from the system is better than a manual adjustment. The same is valid for the regulation of the light intensity which is mechanically adjusted with a perfect grey scale spectrum.

As already mentioned, the basic principle of réseau measurement is the orientation of the sensor via a mesh. To obtain the correlation between réseau- and sensor system, a transformation between the two systems has to be defined. Problems occurring from the orientation of the réseau system are for example the different mesh sizes of the initial system, differing focal lengths of the sensor optics and a possible rotation of the réseau system in correlation with the sensor system. To avoid that this proceeding becomes slow and difficult, an algorithm was implemented which identifies basic scales and rotations automatically: by initialising the mesh system on only one mesh in the center of the scanner, a low error rate to all sides is assured. Given that in many cases the first mesh is chosen incorrectly, the position has to be corrected. When the sensor focuses at least one mesh, this means that at least one réseau cross is reflected in the digital partial image and is therefore measurable. If no crosses are visible due to extreme interferences, the algorithm sets a new mesh. When four crosses are found in the first attempt, the mesh is regarded as being initialised. Otherwise, the scanner has to be moved in such way that the cross found is placed into the corner of its quadrant. For this purpose, the height and width of a pixel referring to the scanner system must be known in mm. To receive the necessary scale, the scanner is moved in x- and y- direction for a quarter of the known mesh dimension. It is then tried to recognise the same cross. The viewfinder is limited in such way
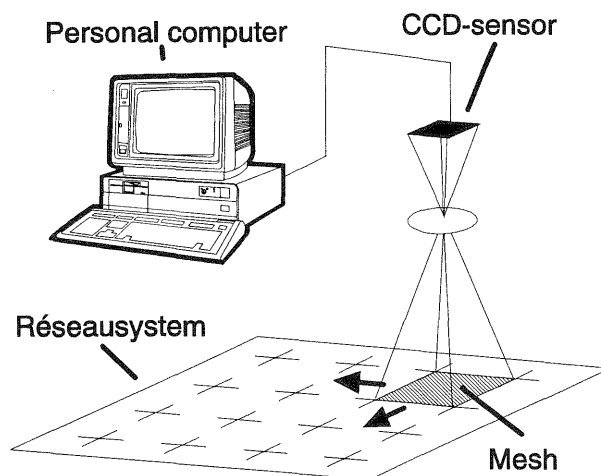

Figure 2: Principle of réseauscanning

that no identification problems are possible. Now, both scanner distances and the corresponding frame grabber positions at which the crosses were identified are known. Now the scale can be derived from the quotient of the scanner distances and the positioning difference on the image board. With this scale the scanner position can be corrected easily that the mesh can be focused centrally by the sensor. Then the scale that had been dependent on the positioning accuracy of the scanner can be identified through the distance of the réseau crosses in the digital partial image and the dimensions of the réseaus.

Figure 3: coordinate systems

Orientation of the measurement images
There are two basic possibilities when orienting measurement images: on the one side, images can be oriented with a preilluminated réseau, on the other side it is also possible to orientate images with a wide mesh réseau. In the first case, no réseau plate is necessary on the scanner. The initialisation of the scanner as described above is effected directly when orienting the images. The two methods only differ in one feature: in the first case, the meshes are taken for identifying position and rotation, in the second case, the crosses of the réseau are the reference. In principle, the two methods are identical. From the identified signal (mesh or cross) the rotation of the image system to the sensor system is determined. With this identification together with the information given on the réseau it is possible to position directly above the second relevant signal. With every further measured signal, the transformation between the systems is being improved successively

until four signals are measured and the affin transformation can be calculated with an overdetermination.
This method allows the calculation of a transformation between image- and reference system by giving only one signal per image. Any other positions in the image system are determined automatically. It is also possible, to orientate the images manually to make a measurement of difficult images possible. The signals which determine the orientation can be chosen in the interpreter files.

MEASUREMENT

Optimising the Measurement
In order to assure a fast measurement, calculations, sensor movements and switching the illumination regulation have to be parallised.

In pictures without preilluminated réseau (Figure 4) it is necessary, to keep the following measurement procedure for one point:
To select the réseau crosses and to be able to initialise the meshes, it is necessary to change into the on-light mode. During the light adjustment, the sensor is positioned above the mesh with the signal to be measured. The image is then given in the frame grabber. Initialising the mesh in this partial image and changing into the through-light mode is done simultaneously. The time, necessary for measuring the target mark, is used to prepare the scanner for further measurements. In the on-light mode, the scanner receives the order to position above the next mesh. When the measurement is finished, the scanner is already placed above the next mesh in the on-light mode. Therefore, on-light recording is possible without any delay.
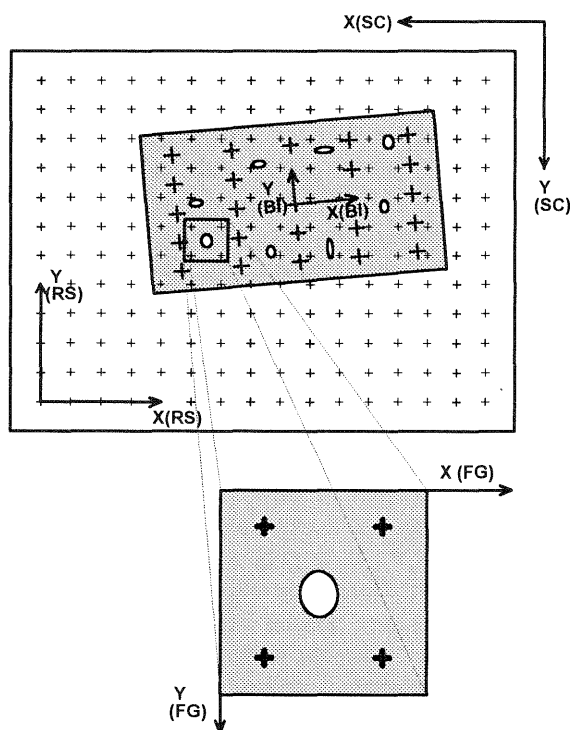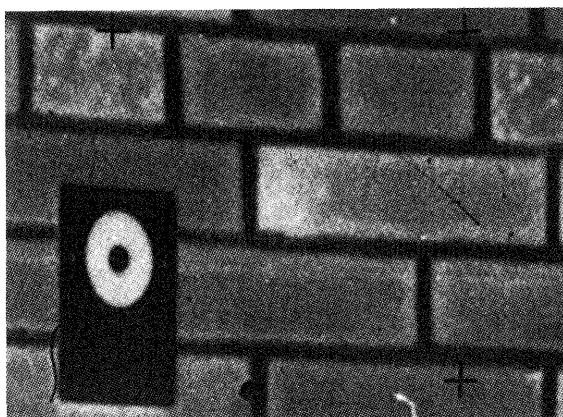

Figure 4: Picture without preilluminated réseau

In images with a preilluminated réseau (Figure 5), the measurement is structured as follows:

At first, the mesh to be read is focused by the sensor and the newly calculated through-light intensity is adjusted for the measurement (compare homogenising the digital partial images). When the partial image is given into the frame grabber, the sensor is moved to the following mesh and the next illumination intensity is adjusted. The time, the scanner requires is used for initialising the mesh and for measuring the signal.
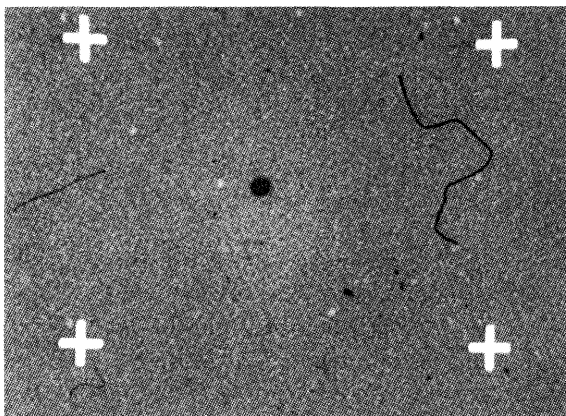

Figure 5: Picture with preilluminated réseau

Homogenising the Digital Partial Image

To assure a fast and safe signal measurement, it is necessary to avoid interfering influences by means of digital image evaluation or adjustment when snapping the digital partial image. These are the prerequisites for a fast image identification and for highly accurate positioning.

For accurate measurement, an even illumination of the image is essential. An over-exposure would falsify the objects relative to the background. If, for example, a black ellipse has to be measured, its edges would move towards the center in the case of over-exposure as the bright background would shine into the ellipse. In another extreme case with an under-exposure of the image, a black ellipse would not have sufficient contrast against the black background and the edges could not be identified.

The fact that negatives always show an uneven illumination and the necessity of a perfect illumination of the image for an accurate measurement results in the demand for an automatic postadjustment of the light used for snapping the image. This demand was introduced into MIROS routines as follows:

During the orientation, the through-light intensity, the user adjusts for measuring réseau crosses is stored. For any later measurement, this value is taken as a starting parameter.

The algorithm for post-adjustment of the illumination intensity does not determine the intensity explicitly from the grey scale which would lead in the case of erroneous measurement to false light values and to the end of the procedure. The grey scales of the signals are taken and then, with the example of a white signal, the correspondence between the grey spectre and the maximum grey spectre value can be determined. Should this be the case, the illumination intensity is decremented or incremented. With this procedure, the illumination intensity always varies around the optimal value. If a signal is not measurable, the illumination intensity is not post-adjusted as no reference values are available.

In contrary to the regulation of different illumination intensities as described before, only one illumination intensity is regulated for images with réseau illumination. In retroimages, the réseau crosses are visible in the through-light for orienting the sensor and it is therefore possible to effect the orientation of the sensor and the measurement in the same image. The light cannot be focused on the crosses or the ellipse to be measured as this would mean that one of the signals would always be insufficiently illuminated. For this reason, the grey scale values of the background are taken for illumination regulation. After the measurement of the crosses and after the measurement of the signal targets, a medium grey scale value is chosen from the area in which only background grey values are placed. This grey spectre value is regulated on a value that makes possible both, the measurement of the white réseau crosses and of the black signal targets. This procedure assures a sufficient contrast of the targets and the réseau crosses to the background.

Only three important grey values occur in the retro images: crosses, signal targets and background. Therefore, the capacity of the frame grabber to differentiate between signals and surroundings can be used. From the original image, two copies are made within the frame buffer, one for isolating the crosses, one for isolating the signal targets. In retro images, signal targets are always black ellipses. This means that the significant grey values for measuring these signals are always in the lower grey value spectre. For this reason, recordings within the screen buffer is always effected via a threshold Look-Up-Table. Its purpose is to give identical copies of the grey values from 0-50 and to take a value of 50 for any others. Thus, bright interferences are eliminated and darker interferences are reduced. The only sharp gradients in the image are then the edges of the ellipse which can then be found and measured easily. A similar operation is effected for the réseau crosses: any grey values below the threshold value of 150 are set at 150, grey values above this value are accepted. To react flexibly on the different

negative attributes, the threshold values, for isolating the crosses and for isolating the ellipses, are also adopted to the brightness conditions in the basic image. The grey values of the original signal and the background grey values are taken as a reference for this reglementation. For the threshold value of the réseau crosses, the value of the background is used and increased by 20% of the difference between background value and the grey spectre value of the réseau crosses. For the ellipses, the brightness value is increased by 90% of the difference to the background and is used as a reference value. The true regulation is then effected in small steps as for the adjustment of the light intensity of images without réseau preillumination. Should the threshold value be lower than the calculated reference value, the threshold value is incremented, otherwise decremented.

A prerequisite for the described adaptation of the illumination intensity and the threshold value is the even movement of the sensor over the image. It is impossible, to adapt the illumination intensity to the illumination differences on the negative when subsequent measurements are effected in totally different parts of the negative. A second advantage can be seen in the fact that the movements of the sensor are decreased and possible delays before sensor positioning can be avoided. This results in the necessity to assure the scanner movement to the closest point and a gradual changement of the brightness. The adaptation of illumination intensities and of the threshold values can then be effected. This rearrangement of the points happens in a step taken before measurement.

USER INTERFACES

The development of a complex user interface was avoided in order to make possible a later introduction of specific customer demands. The experienced user is able to create his own measurement programs, adapted to his own demands.

For standard applications, on the one hand, given interpreter files can be used, on the other hand, program generators can be applied which are independent from the MIROS measurement system. The command structure and the interpretation of such an interpreter file are similar to the batch programming in a DOS shell in order to guarantee an easy approach in the possibilities of the interpreter. To give an overview of the work of the interpreter, some of the implemented commands are described in the following:

1. Include
   allows to import command sequences to the actual program position. With this command, standard command sequences can be combined as a macro and be included.

2. Label
   define positions in the measurement program to which jumps with the commands "Goto" and "If" are possible.

3. If
   makes possible to effect a conditional jump. The functions 'Yes-Pressed' and 'No-Pressed' have been implemented which react to a Yes or No of the user. Further functions can be implemented.

4. System
   executes a DOS command which is given as a parameter or starts a DOS shell. This shell can be left with the "EXIT" command.

5. Getpicture
   Starts the image orientation. Image numbers, réseau types and as an option also the information which side of the negative is on top are required.

6. Automode
   sets the level of automation. One can chose between 'ON', 'OFF' and 'HALF'. With the 'ON' parameter a fully automatic measurement is chosen. With the 'OFF' command a manual measurement is set. The 'HALF' command activates this manual measurement after the automatic measurement has failed (major signal disturbances).

7. Meas
   is the command that starts the actual measurement. As parameter amongst others, the file from which the points to be measured are taken, is disposed. In this file start and end lines can be named.

RECOGNITION OF MARKS

Measurement of Ellipses

Circular point signals are fixed as target marks on the object. This assures a conform copy in the image. The measurement of positions in the negative is thus restricted to the measurement of ellipses, as circular signals are always reflected as ellipses, because of the perspective image. As a point coordinate in the image the center of this ellipsis is determined. The problem to be solved is a interference tolerant identification of the margin points of this ellipsis.

Problems that might occur are the following:

- Is the approximate value, which is the starting point for setting the margin points, within or without the ellipsis?
- How can this approximate value be improved with a fast and safe algorithm?
- How distinctive are the margins of the ellipsis, are all margins homogeneous, how can the margins be recognised by avoiding errors?
- Are all recognised margin points part of the ellipsis, or do they just represent areas of high grey scale differences?
- Is the recognised object a measurement target, or just a disturbance on the negative, in the shape of

an ellipse?

To give an idea of how such an measurement mark is represented on frame grabber, the following grey scale picture of a well defined ellipse shown:

```
152 132  97  52  36  37  31  27  31  40  54  77  85  78 106
142 122  87  42  25  21  13  12  20  24  32  56  69  72 109
127  97  70  36  11   5   5   5  11  13  19  42  60  71 106
116  81  50  25   7   1   0   0   2   6  15  35  52  70 102
107  68  39  16   4   0   0   0   0   3  10  24  47  69  99
 87  53  34  16   0   0   0   0   0   2  14  39  65  95
 76  53  30  10   0   0   0   0   0   0   8  31  61  88
 76  58  31   2   0   0   0   0   0   0   7  22  50  88
 85  56  21   0   0   0   0   0   0   0   3  16  43  86
 88  52  13   0   0   0   0   0   0   0   1  12  35  74
 85  53  14   0   0   0   0   0   0   0   0   6  27  68
 81  53  18   0   0   0   0   0   0   0   0   5  26  62
 90  64  23   0   0   0   0   0   0   0   0  10  31  60
100  71  22   2   0   0   0   0   0   0   0  14  38  68
112  82  31   8   0   0   0   0   0   0   0   8  34  66
113  70  30  10   0   0   0   0   0   0   0  11  30  60
103  61  33  15   2   0   0   0   0   0   0  15  36  63
 92  58  31  14   4   0   0   0   0   0   5  22  47  70
100  81  46  17   6   0   0   0   0   4  14  27  48  75
115  92  52  17   3   0   0   0   0   6  17  30  52  81
133 105  60  23  14  11   4   0   0   0   5  20  39  76 109
139 109  71  44  28  10   8   6   3   7  14  24  44  87 125
153 132 100  64  40  16  15  16  13  15  22  35  60  95 135
173 165 133  84  60  33  25  23  19  22  33  50  79 105 143
```

In order to show the measurement on an ellipse in detail and how the problems described above can be solved, an example of an ellipse measurement procedure is given.

Based on an approximate value, seven straight lines in 50° ankles are set and the highest gradients of the grey scale on these lines are identified. The coordinates of these gradients are taken as potential ellipse margins. With these seven coordinates a ellipse with minimal error is approximated. If the initial approximate value was not focused in the ellipse it will in most cases be impossible to find an ellipse with a sufficiently small error rate through these points, meaning that the approximate value has to be improved. Should the adjustment succeed erroneously, the same procedure must be repeated with a number of straight lines selectable by the user. In this case, the adjustment of an ellipse with a relatively high number of straight lines will fail if the approximate value was not situated in the signal to be measured. Also in this case the approximate value is improved afterwards.

If the approximate value was initially placed within the measurement mark the test described above is successful and the real measurement with an amount of straight lines adjusted by the user can be started. The value resulting from the seven-lines-test is taken as an approximate value for the accurate measurement. The advantage is, that the second initial value is placed in the center of the ellipse and therefore the straight lines starting at this point cross the margins of the ellipse at a 90° ankle. For this reason they cross distinctive ellipse margins, which can be calculated with high accuracy. Based on the error rate of the ellipse adjustment it is possible to distinguish between objects and interferences. Should this interference be a perfect ellipse, it is impossible to avoid that this false ellipse is recognised as a signal mark. A further hint to identify such false ellipses is the size of this mark in the frame grabber system. In general, calculated values are taken as an approximate value for measuring the ellipse. These values result from approximately known object coordinates and the recording position. As this also gives the distance between signal marks and recording position it is possible to calculate the size of the signal marks in the negatives. This calculated size is used for the identification and control of the signal.

The approximate value (or the potential ellipse focus) must be improved in the following cases:

- the error rate resulting from the adjusting ellipse of the first test or the main measurement is too high
- the difference between calculated and measured size is too high

This is achieved by means of search of gradients on a helical path around the starting point.

For this search it is presumed that the starting value is not situated within the ellipse. In case of black target marks it is then searched for a transition from bright to dark on the helical path. Having found such a transition of sufficient size the search is continued until a transition from dark to bright is found. The center of the connecting line is used as the following starting point for the described ellipse measurement. To avoid an ellipse adjustment on an already tested position, the positions on which the adjustment had already failed, are stored and compared to probable new positions. Only if the positions differ significantly from the existing ones, a new ellipse adjustment is tried. This procedure avoids repeated failing adjustments, as for example on bright to dark margins.

A one-dimensional folding on a seven scale field is used to identify the transitions. The corresponding vector is the following:

$$-3 \quad -2 \quad -1 \quad 0 \quad 1 \quad 2 \quad 3$$

The gained folding values correspond roughly to the first derivation of the function defining the basic grey value spectre. This first derivation is examined under the aspect of finding a maximum or a minimum. The exact position of the maximum is determined by calculating the center point above the folding values. This maximum, represented by sub-pixel values, corresponds to the turning point of the grey scale function. This turning point is the requested transition from dark to bright or vice versa.

The search of gradients by means of a folding has the advantage of being tolerant against interferences as it takes into consideration a relatively large spectre of grey values. This tolerance is intensified by the additional calculation of the center point above the detected folding values.
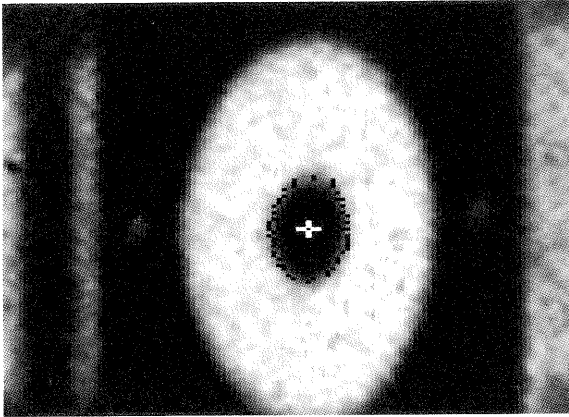
Figure 6: Recognised ellipse

The segments are always divided into an inner and an outer part. For segments covering one bit of the code both parts are identical. However, the segment representing the starting mark differs in its parts. This difference allows the identification of the starting mark. For this purpose the grey spectre is examined on two radiants around the recognised ellipse. The starting mark is found when the grey values on the inner and the outer radiant differ significantly. Starting at this mark, a grey course is recorded on a radiant around the ellipse. This grey profile is then examined under aspect of bright-dark variation. As the sectors containing the codes are known by the number of coded bits, the centers of these sectors can be emphasised in the correlation. This assures a very safe identification.

Identification of Ellipses

The automatic identification of signals placed on the object is an important step towards comfortable usage and efficiency during the measurement procedure. This kind of correspondence between points and point numbers is very significant when the image carries retro-reflective target markings. The normal run consists of image orientation with only a few known points and a calculation of the approximate values for the remaining object points. Because of the lack of natural object information, this manual coordination can only be effected by the help of special target marks or additional point numbers.

A new way is the use of target marks with point numbers that can be identified automatically. In this case, only the positions of the target marks must be known, not their numbers. By means of digital image processing, the signal of the point number is recognised after having measured the target mark.

The marks have to fulfil the following demands:
- Tolerance against interferences
- Possibility to control the identified point numbers
- Efficiency of the technique
- Possibility of adapting same type target marks of different sizes

Target markings carrying a binary segment code on the single segments have proved to be most resistant against interferences (segment marks). This kind of code uses almost the whole surface of the signal mark for point coding and only it's large surface protects them from interferences or inaccuracy in the ellipse detected before.

Using a nine-bit-code requires nine segments for the bits and one segment marking the beginning of the code. With nine bits it is possible to code 512 different marks, sufficient for common applications.
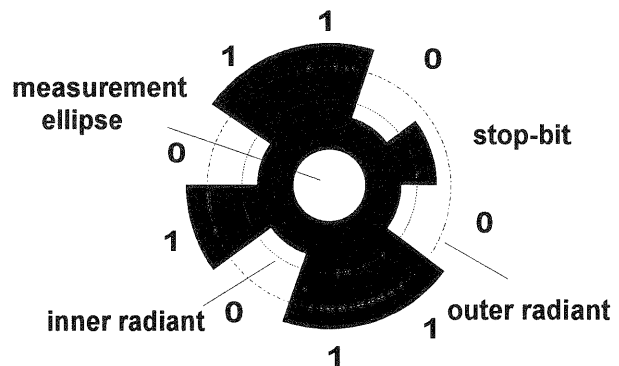

Figure 7: Segment mark

The examination of the grey value spectre is effected first in the outer part of the segment marks and then in the inner part. Only when both evaluations correspond the point number is regarded as being recognised.

The size of the target mark are variable because the sizes of the inner circle, the radiant of the entire mark and the separating radiant between inner and outer segment can be adjusted by the user. Furthermore, the number of coded bits can be adjusted in a parameter file from the outside.

REMARKS

The MIROS measurement system was intended to be a semester paper and has meanwhile reached the standard of a commercial product. In cooperation with Rollei Fototechnic and the international industry, various performance tests proved the flexibility, reliability and measurement accuracy of MIROS.

The successful completion of this measurement program was made possible with the support of Rollei Fototechnic. With special thanks to Prof. Dr.-Ing. Günter Pomaska and Dipl.-Ing. Günter Suilmann.

LITERATURE

[DW91]   Jürgen Dold, Wolfgang Riechmann, Industriephotogrammetrie höchster Genauigkeit, ein neues Meßsystem und dessen Anwendung in der Luft- und Raumfahrtindustrie, in Zeitschrift für Photogrammetrie und Fernerkundung, Heft 6/91, Herbert Wichmann Verlag Karlsruhe

[GP88]   Günter Pomaska, ROLLEIMETRIC - ein Systemkonzept für photogrammetrische Ingenieuranwendungen, in Zeitschrift für Photogrammetrie und Fernerkundung, Heft 6/88, Herbert Wichmann Verlag Karlsruhe

[GS92]   Günter Suilmann, Rollei 6008 metric - a new camera for industrial photogrammetry, XVII ISPRS Congress 1992

[LW88]   Thomas Luhmann, Wilfried Wester-Ebbinghaus, Digital Image Processing by Means of Réseau-Scanning