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Automatic Control Point Measurement

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ABSTRACT

The measurement of ground control points is an important task for the absolute orientation of stereo models, for digital aerial triangulation or for the registration of satellite imagery. In the Digital Photogrammetric Systems existing today this task is usually completely performed by a human operator. There exist, however, methods, that can identify and/or localize control points or control structures in an automated, but very seldom in an autonomous way. A short evaluation of the performance of some representative methods is given. The measurement of signalized ground control by image matching and by feature extraction tools has shown similar quality than the manual measurement of such points in digital aerial or satellite imagery.

1. INTRODUCTION

After completion of the interior and relative orientation, the photogrammetric stereo model must be scaled, translated and levelled with respect to a ground reference coordinate system. For this datum definition a correspondence between image points and points on the ground has to be established. This procedure is called absolute orientation. The coordinates of the ground points must have been determined precisely, which is quite often done by geodetic means. The corresponding points in the image must be identified and measured precisely. With photogrammetric point determination by the method of bundle block adjustment a large number of discrete points in the ground coordinate system can be determined as well. The photogrammetric point determination is used either to provide control points for the single stereo models, to densify a control point network, or to determine a large number of e.g. cadastral points. For the rectification of satellite imagery, an image-to-image registration or an image-to-map registration has to be performed, as the position and attitude data of satellite sensors are not sufficient for the rectification for most applications.

The automation of the photogrammetric orientation procedures has for quite some time been a research topic in Digital Photogrammetry. The interior- and the relative orientation have been solved, using image processing techniques and are now available in Digital Photogrammetric Systems. Those procedures require, if at all, very little user interference during the measurement. In close range applications the possibility to use well defined targets, has since longer allowed the automated identification and localization of control points. For topographic applications the emphasis has been on automatic point transfer (Helava, 1988, Tsingas, 1991, Ackermann, 1995) in aerial triangulation (AT). The point transfer has been solved in a fully automatic way, but the measurement of signalized control points is not yet automated, i.e. it is usually performed manually. For the registration of satellite imagery there are nowadays the first autonomous systems available for specific sensors, based on specific ground control point databases.

We will first have a look on the ground control points used today, that have been optimized for use in analog and analytical photogrammetry. We will examine how the type, design and selection of points have an impact on the automation using image analysis methods. We will discuss some current approaches using image analysis to measure ground control points automatically and give a short evaluation of their performance. Some of the methods had been tested on selected image material. The results of this empirical comparison are presented and discussed.

2. CONVENTIONAL GROUND CONTROL POINTS

A most important condition for ground control points is that they can be easily defined. They should further be unique and they should be locatable with high precision. In practice signalized points, selected natural points and selected artificial points are used as ground control points (Kraus, 1984). The highest precision can be obtained with signalized points. Requirements on appropriate size and shape and sufficiently high contrast to the background have to be fulfilled. Round and square targets or crosses with suitable background are most common. Also painted targets are used. The colour of the signals and the size have to be selected. The size of available measuring marks and the problems of dependency of the signal size from the contrast have to be considered. Artificial points are physically marked in the emulsion. Carefully selected and marked points allow almost the same accuracy as signalized points. Due to the principal similarity to signalized points they are not considered any further here. Clearly identifiable natural points, related to topographic features, are chosen to avoid expensive signalization. Those can be corners of buildings, fields, stones in fields or the ends of a paint stripe. Points in shadow areas or near water should be avoided. The natural points as well as the signalized points are described in a sketch to assist the identification in the image.
Looking at these requirements we easily can imagine the difficulties to automate the measurement of ground control points of whatever type. We have to observe many well defined rules how point types are chosen, how points are selected, and signalized and how their identification is ensured. We have to detect, identify and measure the centre of a specific point in the image. For that purpose the representation in the image has to be compared to the semantic description of the point on the ground. We have to choose a representation that can be matched and that is valid for all the control points occuring in a block. The representation chosen should allow a robust and reliable identification and localization and should not be disturbed by the background. Here we can't choose arbitrary points, that suit best the available image matching method, like we can do it for relative orientation. We have rather a problem like with the measurement of fiducial marks, but with disturbing background, varying image scales and distortions and without a specific, well defined model. Due to the variation of points in the image and their 3-D nature on the ground, we have to realize that simple matching methods might not always be applicable. These tasks require object recognition and object reconstruction, i.e. image understanding, which is rather difficult to automate.

3. PROBLEMS TO AUTOMATE THE MEASUREMENT OF GROUND CONTROL POINTS

If we look more closely on some of the problems for detection and localization of ground control points we will quickly find out, that we have great problems to design or select suitable models, even for signalized points, that allow homogeneously good recognition over a whole block of images. The representations of models of control points are often in vector format and thus not directly applicable in raster based matching methods. If natural points are selected the modeling problem is obvious, as practically for each point a different reference model has to be provided. The model is often selected in other image material or from map data and most likely with user interaction. Those points are rather chosen for long term usage to be applicable also in later projects with the known problems of changes in background, of different view points, of different image scale, etc.
If signalized points should be used for ground control we have to realize that the conventional rules for targeting are not designed to fulfil the needs of image analysis with respect to size, shape and background of signals:

- Signals are often very small. Amoderate scanning resolution results in some pixels diameter only. This makes it almost impossible to detect the signals automatically in a larger image patch. A

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small size, as such, might be perfect for measurement by the human operator, but it provides great difficulties for image processing tools.
- Signals are often corrupted, or only partly visible, which are no real problems for the human operator, but for automation.
- The background is sometimes painted, sometimes natural and as such inhomogeneous, which makes proper modeling difficult. This heavily disturbs all automated methods.

In figure 1 we can see how five signalized points appear in two images of an aerial test block (Gülch, 1994). In figure 1a 5x2 image patches of size 128x128 pixels are presented. Figure 1b provides a closer look on the same signals with image patches of size 30x30 pixels. The signalized points (crosses) are only some few pixels in diameter. They vary in size, they have different rotation and backround and they are partly distorted.

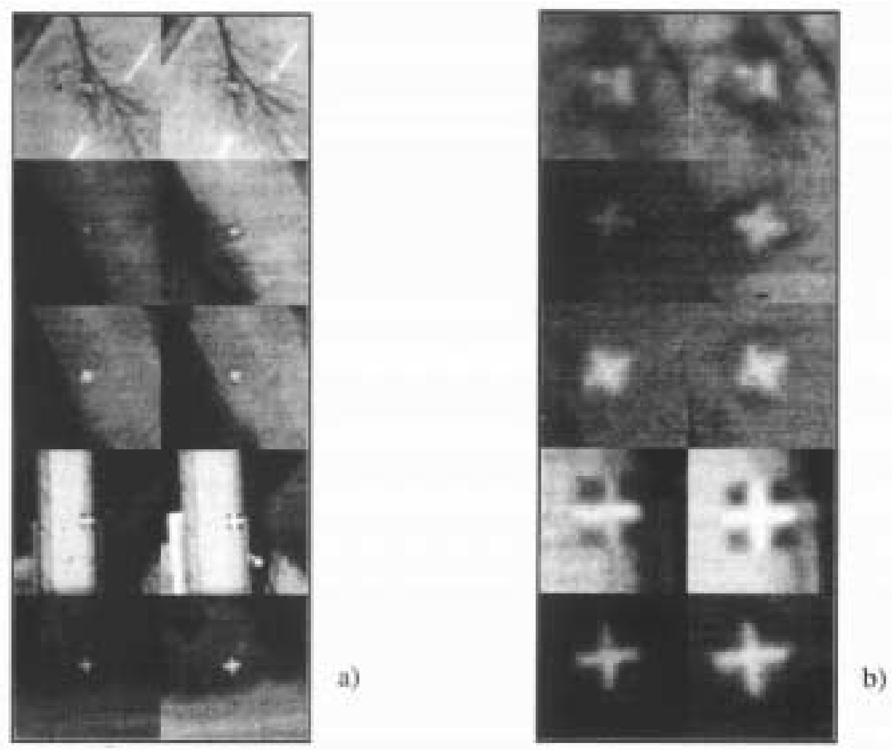

Figure1: Five signalized points in images #11 (left) and #12 (right) from the 15 µm OEEPE Digital-AT data set (Gülch, 1994). a) Overview. The patch size for each signal is 128x128 pixels. b) Close view. The patch size for each signal is 30x30 pixels.

Beside the great technical difficulties we can identify at least two other reasons which could let us hesitate to automate the measurement of control points: there is but a small number of signalized control points in many blocks to be measured compared e.g. to the number of points used for DTM extraction. Secondly: the GPS aerial triangulation (GPS-AT) has reached the stage of practical applicability (Burman and Torlegård, 1994) and in real aerial triangulation projects it has been shown that under certain conditions only a minimal amount of ground control points is required. The human operator measures those points very fast and much more reliable than any other method today.
Under these circumstances it is of course quite reasonable to ask: why should we at all try to automate the measurement of control points? There are some good reasons to attack this problem:

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- If we want to convert to Digital Photogrammetry in practice, we have to try to automate those parts of the production chain from the aerial images to the map, that are best suited for automation. The block triangulation is a major link and it has already reached a very high degree of automation, as far as the point transfer of natural points and the block adjustment is concerned. Any type of user interaction, like the measurement of signalized control points, also for absolute orientation, reduces the efficiency of such a link. This holds even for the image-to-image or image-to-map registration for satellite imagery.
- The manual identification and measurement of ground control points still can take about 10-20 % of the human operator time for one (non-GPS) model in AT. To reduce this time further, we can at least leave the interpretation to the human operator, but provide tools that assist in the measurement. This strategy is actually followed by several vendors of Digital Photogrammetric Workstations. It keeps the possibility open for increased automation as soon as it becomes available and feasible.
- The GPS-AT is so far only used in a small amount of AT-projects and it will probably not be suitable for all image scales, all projects or all countries (Burman and Torlegård, 1994). For quite some while we will have a large amount of conventional blocks, so there would be a need for automation of the control point measurement. This view is supported by current efforts of various national mapping agencies to develop or integrate digital aerial triangulation in their production chain. The GPS-AT on the other hand side can substantially support the detection of ground control and other signalized points, by providing approximate values of high quality.
- The traditional photogrammetry is point oriented, which provides difficulties for quite many automation tasks. We know, that a human operator uses the neighbourhood of a point for identification and for the measurement. There are sketches of the points available, that include higher level structures and features to detect ground control points. There is a definite chance to solve the detection and the pointing problem, by leaving the point wise thinking and adapting to a new concept based on control structures.

We realize that we might not be able to currently perform the control point measurement in a fully automatic, autonomous way, at least for aerial imagery, but we definitely have a chance to approach it in an automated, more interactive way where the measurement itself might be automatic, but the detection is supported by a human operator. We can further see, that we might have to leave the point type thinking with small image masks for the control point and instead focus on control structures that would support automated image analysis methods in a better way.

4. SOME CURRENT METHODS TO DETECT AND MEASURE GROUND CONTROL POINTS AND STRUCTURES

There are many methods applied today to measure control points in digital imagery in an interactive, automated or sometimes even automatic way. Control points are given as artificial or natural image masks or as single features or structures in 2-D or 3-D. Some of the methods are attacking the detection and localization problem in a common frame, others solve either of these problems and are dependent on human interaction. Those methods which automate the measurement are, however, suitable for assisting the human operator.

4.1 Manual measurements of control points in digital imagery

The most common form of current control point measurement in the digital environment is by human operator without any automation. It requires display and control devices, that allow subpixel precision. A high resolution screen with a large field of view, zoom facilities, roaming, a sub-pixel cursor and

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movement control are the major items required. The human operator has to deal with a smaller field of view compared to an analytical plotter. On the other hand side there are image processing tools available in the digital environment, that allow real-time contrast changes, edge enhancement and graphical superimposition to support the measurement. A more automated, but as we will see not completely problem free way, is to give the approximate location by the human operator and to apply on-line matching with some of the methods given below.

4.2 Raster based matching of artificial and natural image patches

The most commonly used matching methods in digital photogrammetric applications are raster/area based matching and feature based matching methods. Both methods are applied for the automated measurement of control points.
Raster based matching methods, like Least Squares Matching (LSM) or Crosscorrelation (CC) are used to match an artificial or natural image mask to the image of the signalized point. Both methods have been applied in the empirical test. The major task for the human operator is to provide a suitable mask to measure all signals in all images. The mask contains a model of the signal, which is in the simplest case e.g. a uniform, white signal on a dark background. The size and shape of the signal has to be determined from its ground size and the image scale. The major problem with mask matching is determining the exact position of the control point and not the lack in precision of the estimated parallax. If the surrounding of a signal in the patch is not homogeneous, or if the signal is corrupted, even a well defined, symmetrical mask can be placed off the centre point of the signal. In (Hådem, 1994) some solutions are given to at least reduce the effect of non-uniform background intensity. It may be recalled, that a low standard deviation of parallax or a high correlation coefficient, two commonly used criteria for high quality of matching, are no criteria for correct pointing.
For satellite imagery high resolution aerial image patches (natural control point chips) are used as ground control objects (Malmström, 1986). A scheme has been developed to match the control point chip and the satellite image given in different resolutions with CC and LSM methods. The detection problem was not solved. For a LANDSAT scene the control point measurement with matching techniques yielded better results than manual pixel pointing on the screen.

4.3 Feature based matching of natural image features

In a system for autonomous registration of SPOT, Landsat Thematic Mapper and NOAA AVHRR imagery (Holm, Parmes, Andersson and Vuorela, 1995) image features instead of image patches are used. Ground control features (lakes/islands) are automatically extracted from a nationwide Land Cover Classification (reference image), produced from Landsat Thematic Mapper and from the new satellite imagery using a segmentation procedure. A coarse approximation is automatically provided by the sensor data stored in the image headers. A preliminary matching is performed that yields potential candidates based on the similarity measures of the extracted regions, like perimeter, area or region type (land or water). A final, robust consistency matching based on a planar object surface model is performed, which eliminates ambiguities and yields the affine transformation parameters between the images. Such a transformation can handle a certain amount of time dependent differences in the boundaries of the ground control regions. A final global or local matching of the rectified and the reference image can validate the quality of the transformation. Also image mosaics and digital map information have been successfully applied as reference for some Landsat TM and NOAA AVHRR imagery. This method has proved to be very useful for mid- to low resolution satellite imagery given a quite regular coverage with water bodies over the whole country. For other countries and high resolution satellite imagery, or even aerial imagery, this approach could be adapted to other type of features, most likely linear features and structures, that can allow higher precision than regions.

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4.4 Relational matching of 2-D model and image features

Also relational matching is applied to detect and measure ground control. In (Vosselman and Haala, 1992) the relational description of the model of large linear features like roads is matched against features and their relations, extracted in the image. This relational matching is realized as tree search method. It requires no approximate values. It is scale and rotation invariant. The search time is usually long and very difficult to predict. It is very much dependent on the number of features to be matched, on the quality of the image representation and on the seldomness of the attributes of the control points. Tests have been performed with large features on images of medium scale that showed the potential of this method. The method is well suited for the detection of control points if the above mentioned problems are solved for practical applications.

4.5 Image feature extraction to measure 2-D signals

In (Gülch, 1994) an image feature extraction approach to solve the pointing problem is presented. The objective is to determine the image coordinates of a signal with feature extraction tools. The detection is assumed to be solved, yielding a small image patch around the signal. It is further assumed that the signal can be described by a closed boundary and that it appears as a quite homogeneous region in the image. This method is applicable for points or structures of cross, square or blob type on dark background and a minimal diameter of about 6-8 pixels.

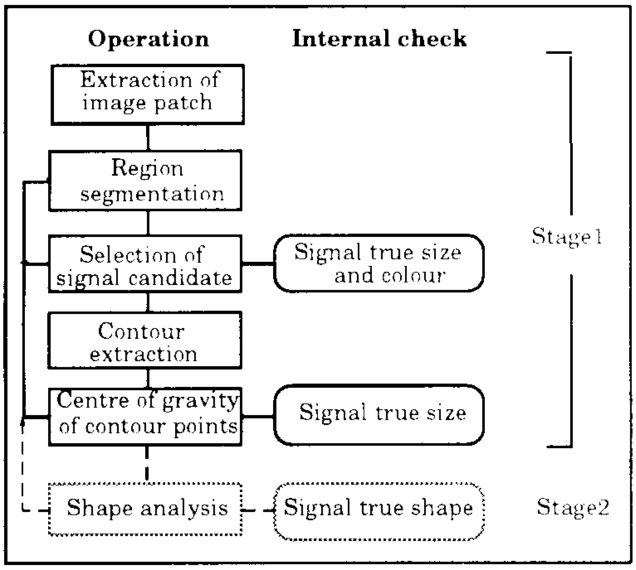

Figure 2: Work flow of the feature extraction procedure with possible iterations.

In a first stage (fig. 2) the background is excluded and approximate values for the centre of the signal are derived by rule based region growing and contour extraction with active contour models. It is regarded as a preparation for stage two where the shape of the contour is analyzed, mainly based on symmetry. This method requires the knowledge of the true signal type, colour and shape, pixel size and some initial setting of parameters, but is quite automated as far as the measurement is concerned. The first stage starts by applying a region segmentation (fig. 3b) to each selected image patch (fig. 3a). A first, quite relaxed global threshold for the homogeneity criteria is chosen by the operator in one image and applied to all others. This corresponds to applying one set of masks to all signals in the case of matching. We check for a signal candidate by some rules, that include the knowledge about true colour and size of the signal. The most brightest region in a patch, which is closed and contains a number of pixels in a given range is regarded as the most promising candidate for the signalized point. If it is too large or not closed, i.e. containing the border of the patch, then a local resegmentation is performed with some more restrictive threshold. If the region is too small then the next brightest region is selected and checked with the same rules. Due to the fact, that the segmentation results in a pixel chain, the outline of the selected region is probably very coarse. To get a refined contour without disturbing background information an active contour model is applied with an polygon approximation of the region border as an initial state (fig. 3c). The parameters for the active contour are selected by the user and applied to all original image patches. The active contour is used until the maximum number of iterations is reached or until the

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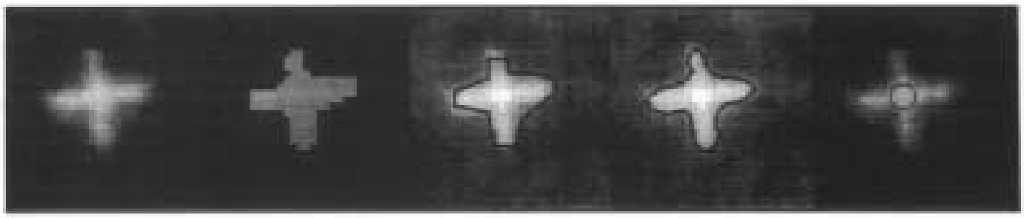
differences at each point between the current and the previous iteration are smaller than a threshold (fig. 3d). At the end of stage one a centre of gravity of all contour points with equal weight is computed (fig. 3e), which is an approximation for the location of the signalized point, and after a failure check the input to stage two.



a)-e)
Figure 3: Extraction of the coarse position of a signalized point (126904). a) Image patch. b) Region segmented image with signal candidate (white region). c) Initial, coarse shape from region segmentation approximated by polygons. d) Contour of one signal, automatically extracted by active contour models. e) The coarse position of the signal (circle) is derived by determining a weighted centre of gravity of the contour points.

The shape analysis in stage two should improve these results further to make the pointing more robust. So far shape and/or symmetry of the signal have not been used. Those aspects can be used to reject a derived point or to trigger a resegmentation with updated parameter sets (similar to stage one) to derive e.g. missing legs of a cross. Alternatively the existing parts of a cross, i.e. number of legs can be identified. This information can be used to initiate a recomputation of the center of gravity with the parts of symmetric input data only including a feature based matching of e.g. a three-leg reference structure. This matching can be point/line/region based with a need for development of suitable similarity measures. So far only the rejection is applied in stage two, based on the number and position of intersection points of predefined circles around the center of gravity with the signal contour.

4.6 Feature based matching of 3-D models of topographic control points

If topographic control points are defined as 3-D wireframe models of roof tops of buildings the detection and measurement can be solved in a most automated way (Schickler, 1992, 1995). The 3-D model is projected into the aerial image, based on a coarse approximate orientation. Line segments are extracted in the image. A pose clustering approximately locates the control point model. A robust elimination yields the best model match and the estimation of the orientation parameters. A final self diagnosis checks the result. This method gave very reliable results in a test on 52 aerial images of scale 1:12 000. The method is, however, dependent on good 3-D models of the buildings. Those can be economically established with Digital Photogrammetry, but they might be not suitable for other, larger image scales due to their 3-D nature. The relief displacement may impose unrealistic requirements on approximate values.

4.7 Feature based matching of 3-D line features in urban areas

Control features can be derived also from a Geographic Information System (GIS). In (Heikkinen, 1994) control features of type 3-D line are proposed for the datum definition. The human operator selects coarse observation windows around the lines in the image. An automated feature extraction detects the lines in the window, which are matched to the control features in object space. Problems

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might occur from the derivation of control lines from GIS data with respect to generalization and precision. The detection in urban scenes will be difficult to automate, due to occlusions.

4.8 Using 3-D control points without identification in the image

In the approach by (Ebner and Ohlhof, 1994), 3-D control points are used without the need for identification in the images. It is assumed that the 3-D control point lies on an inclined plane defined by at least three surrounding object points, which are determined by automated matching. This approach is very efficient for height control points. It is designed for orientation of satellite imagery, where the assumption of the inclined plane is quite realistic and the problems of acquiring the approximate location, i.e. three homologuous neighbouring object points, are simpler.

5. EMPIRICAL TEST ON MEASURING SIGNALIZED CONTROL POINTS

There are no empirical comparisons available for the methods described above. They differ first of all very much in application and initial conditions. To test the potential of the feature extraction approach (4.5) some of the methods have been applied to the measurement of signalized points on a set of signalized points from an aerial triangulation project (Gülch, 1994). The detection was performed by the human operator yielding image patches around the signals. In those patches the signals had to be measured automatically. Here we give a short description of the test set-up and a summary of the major results with focus on the self-diagnosis aspect.

5.1 Test data

As test data set of five signalized points in the test material of the OEEPE experimental research topic 'Aerotriangulation Using Digitized Images' with an approximate image scale of 1:4000 has been chosen (fig. 1). The colour images were scanned in gray value mode at a ZEISS PS1. The images #11 and #12 with 15 µm pixel size have been used. The choice of points was completely arbitrary. The size of the signals (cross type) was about 60 cm in length and about 6-10 cm in breadth on the ground, resulting in about 10 pixels, resp. 1-1.7 pixels in the digitized image. The image patches around the points are in this case only 30x30 pixels, due to the very good approximate values given by operator measurements.

5.2 Test methods

A set of different measuring methods have been used for the comparison (cf. table 1). Three different human operators (OP-0,-1,-2) measured in two different environments. As automated matching methods Crosscorrelation (CC) with a set of eight masks and Least Squares Matching (LSM) with three different masks were applied. The approach with feature extraction (FEX) described in 4.5 was performed with three different parameter settings. The contour extraction with active contour models was performed with one parameter set only. For all measurements a variety of parameters have to be provided by the user. Criteria like standard deviation, correlation coefficient, and convergency (cf. figure 4) where applied to give a quality estimate and to check for failures. Thresholds and parameters for the automatic methods were set globally only.

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Method	**Description**	**Internal quality analysis criteria**
OP-0	- Human operator (#0, Reference) - subpixel graphics cursor and 2-D mouse + keys for fine positioning	- Standard deviation from multiple measurements (<threshold)
OP-1 OP-2	- Human operators (#1, #2) - Simple cursor and 2-D mouse	- Standard deviation from multiple measurements (<threshold)
CC	- Crosscorrelation - Subpixel by biquadratic interpolation - 2 sets of 4 rotated masks	- Correlation coefficient ρ (>threshold)
LSM-M1 LSM-M2 LSM-M3	- Least Squares Matching - 6 affine + 2 radiometric parameters - 3 different masks (M1, M2, M3)	- Standard deviation of parallax (σ_x, σ_y <threshold) - Correlation coefficient ρ (>threshold) - Convergency
FEX-1212 FEX-1515 FEX-2020	- Region segmentation with 3 parameter settings - Contour extraction (1 parameter set)	- Convergency - Area (>threshold) - Perimeter

Table 1: Short description of the methods used for measurement of the signalized points and available internal quality criteria for accepted points.

5.3 Test evaluation

The major objective was to demonstrate the potential of the feature extraction method and compare it to others. For that purpose it was investigated how the methods performed, how flexible they were and how precise and complete the coordinates where determined. The coordinates of all methods were compared to the reference measurement (Operator OP-0).
The manual measurements of signals by three operators differed only very little from each other. A standard deviation of about 2 µm for the coordinate measurement could be reached.
Raster based matching methods require interactive support. The CC method is not rotation invariant and requires a set of rotated masks. The LSM requires good approximate values for the geometric and radiometric transformation parameters. Additional information would be required to ensure correct pointing. Some points could not be measured at all with LSM, as no convergence was reached. Some matches had rather low quality expressed in standard deviation of parallax and correlation coefficient, but still, the external pointing quality was acceptable. This confirms that these internal criteria are useless as measures for pointing quality.
The results with the first implemented step of the feature extraction approach are fully comparable to matching methods and even manual measurements, as far as the precision is concerned. The feature extraction result is either on the same level as all the other methods or it fails completely which can be indicated by internal checks.

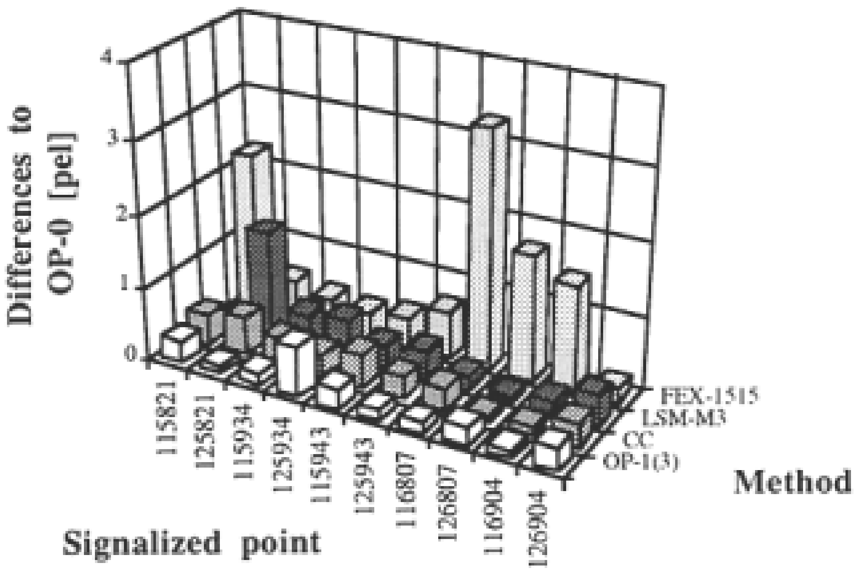

Figure 4: Differences of selected methods (before failure check) to the measurements by OP-0 for all signals. The feature extraction (FEX-1515) is either on the same level as other methods or it fails completely which can be indicated by internal checks.

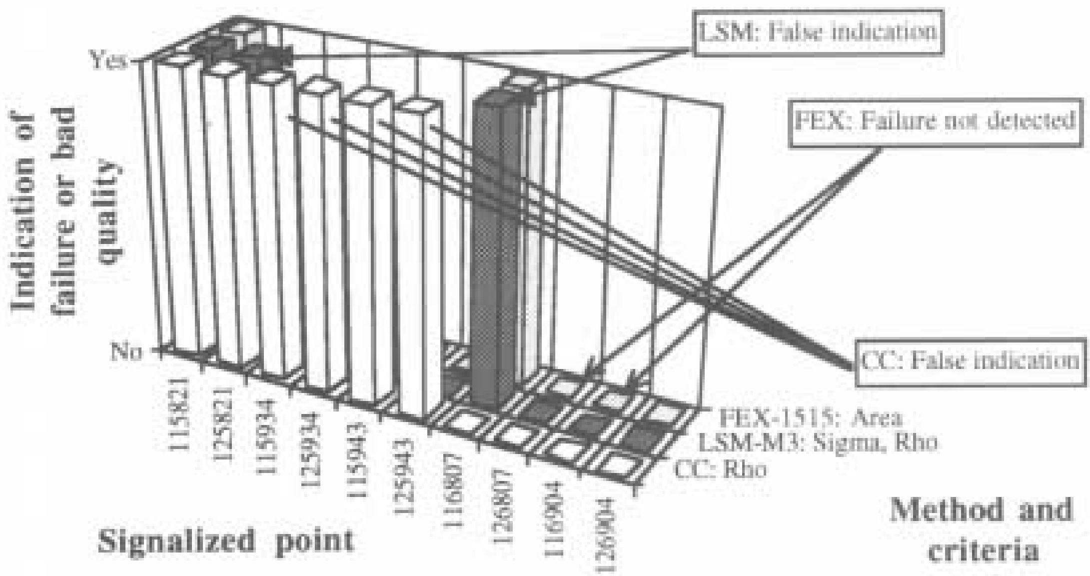

Figure 5: Result of internal selfdiagnosis for selected methods with global tresholds for failure check. For each method some wrong or missing indications occured.

If we would have rigourously applied some rather moderate thresholds for the failure check or self-diagnosis the result would look different (cf. figure 5). At six out of ten signalized points the correlation coefficient for the CC method was Rho<0.75, i.e. these correlations were unacceptable weak, but still at least four of them had a very good external pointing precision.

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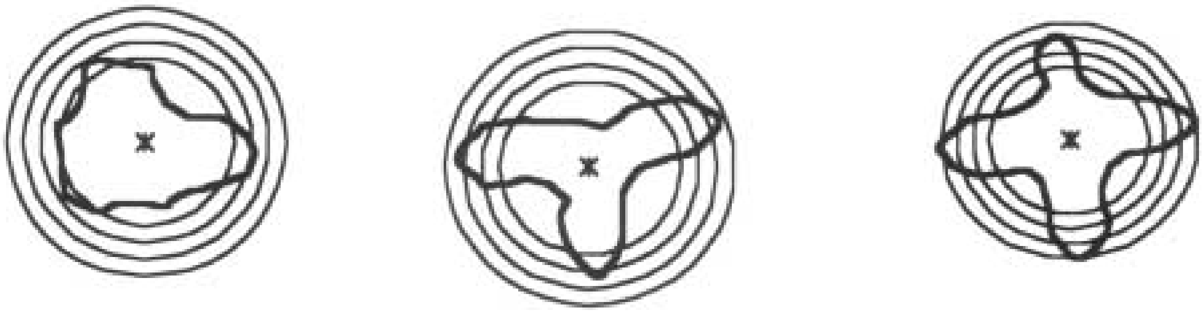

Figure 6: Check of symmetry for contours of points 126807, 116904, 126904 (from left to right) for the feature extraction (FEX-1515) method. Circles with radii of 8,7,6 and 5 pixels around the center of gravity (from stage one) intersect with the contour in different ways. The points 126807 and 116904, which passed the tests in stage one but with bad quality, would have not passed this symmetry test and would have been correctly identified as weak. Point 126904, which was very precisely located, passed this test.

The points 125821 and 116807 would have been incorrectly eliminated in the LSM-M3 matching due to a low correlation coefficient (Rho<0.75) and high standard deviation of parallax (Sigma>0.5 pixel). For FEX-1515 the points 115821 and 116807 have been identified as incorrect due to a small area (area<30 pixel). The points 126807 and 116904 have passed the area tests of stage one, however in both cases less than four legs have been extracted which can be notified by a symmetry analysis (fig. 6) based on circles around the center of gravity with radii 8,7,6 and 5 pixels. For the point 126904, which was very precisely located, four legs are confirmed.

6. CONCLUSIONS

The problems to automate the measurement of ground control points are recognized, with the current effect, that the pointing is done manually in digital images, as the most reliable method. Digital Photogrammetry requires a transition in the concept of ground control from points to larger structures, to reduce the interactive interference. An adapted automation of these tasks could be conceptually integrated into the proposals for automated blocktriangulation by (Schenk and Toth, 1993) and by (Ackermann, 1995).

Matching methods for features and relations can reliably detect large control structures in aerial imagery with coarse or no approximations. GPS flight navigation and INS systems provide image orientations, that can support the detection task. Small features or signalized points require interactive identification, i.e. detection, for the time being. The fact, that already few measured ground control objects allow a coarse orientation, supports the detection of further points considerably.

Conventional rules for signalizing points have to be adapted to the needs of image analysis, to provide optimal size, shape, sufficient contrast and homogeneous background. Smallest possible pixel sizes should be made available for the pointing. Raster based matching methods are hampered by the fact, that they require sets of well defined image masks, that might have to be interactively adapted to different images of a block. The lack of quality criteria for the pointing leaves those matching methods completely dependent on human validation, for the time being.

Digital Photogrammetry is well suited to deal with natural ground control. Image patches from very large scale aerial imagery or even close-range imagery could be used as control point chips to reduce the problems with modelling in raster based matching. This requires the matching of different resolutions to be solved. Even already oriented images could be regarded useful as 'ground' control to be matched to new images, without the need for point identification.

Feature extraction and/or matching of features show great potential to solve the identification and pointing problems in a most automated way. The outlined shape analysis of signals or larger control structures has to be implemented and tested on a larger data set. User interference for initialization will have to be allowed for the time being. 3-D topographic features, like complete buildings or 3-D lines are well suited objects, if the approximation problem, due to relief displacement and occlusions can be solved.

Even if the concept of ground control should finally be adapted to image analysis: in a transition phase both the needs of conventional and digital photogrammetry will have to be served.

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