METRIC RESTITUTION OF TRAFFIC ACCIDENT SCENES FROM NON-METRIC PHOTOGRAPHS

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ABSTRACT

The use of stereocameras for the documentation of traffic accident scenes is desireable but not realistic; the use of non-metric cameras is the normal case. Since 1980 approximately 70 different cases of court expertises have been solved with ORIENT, the institute's own very general adjustment program system, which also students learn to handle.

The paper reports about work flow as well as the workphases in detail.

Computing time, overall working time and costs are proving up that amateur photogrammetry might be a prosperous new field for photogrammetric specialists serving for a larger group of court expert surveyors.

ZUSAMMENFASSUNG

Die allgemeine Anwendung von Präzisionsstereomeßkammern für die Verkehrsunfalldokumentation ist zwar wünschenswert aber nicht realistisch. Im Regelfall werden jedoch beliebige Amateurkameras verwendet. Seit 1980 wurden an unserem Institut etwa 70 verschiedene Gerichtsgutachten technisch behandelt. Alle Fälle wurden mit Hilfe von ORIENT gelöst, dem sehr allgemeinen institutseigenen Ausgleichungsprogramm. Seine einzelnen Module können vom Operateur am Bildschirm mit Hilfe einer photogrammetrischen Kommandosprache aufgerufen werden, mit der auch Studenten umzugehen lernen.

Der Artikel berichtet über den Arbeitsablauf, die Feldarbeit und die Paßpunktmessung, über die verschiedenen Typen von "Paßrelationen" zwischen zwei Punkten (Strecken, Winkel, Lotlinien) oder zwischen Punktgruppen (Ebenen, polynomiale Straßenflächen) und über die Verknüpfung mit den Automodellen. Die Vorbereitungsphase, die Bildkoordinatenmessung, das organisatorisch wichtige Punktnumerierungssystem, die Berechnungen, die automatische Kartierung und die Nacharbeiten werden detailliert beschrieben.

Die Rechenzeiten sowie die Gesamtarbeitszeiten und -kosten beweisen, daß die Amateurphotogrammetrie ein wirtschaftlich interessantes neues Arbeitsgebiet für Photogrammetriespezialisten sein kann, die ihre Dienste einer größeren Gruppe von gerichtssachverständigen Vermessungsingenieuren zur Verfügung stellen.

1. Introduction

The use of stereometric cameras for documentation of traffic accident scenes is desirable but unfortunately not realistic; it is the standard, however, to have non-metric so called amateur-cameras. Any of the Austrian police stations is well equipped with various types of amateur cameras which are a prerequisite for any photographic (and mostly non-metric) documentation. In case of mere car-damages the police may not interfere at all. Then photographs are taken by the parties or by other witnesses.

Photogrammetric court experts are requested
- to check doubtful details in police plans,
- to add missing details in police plans or
- to completely resurvey and reconstruct the traffic accident scene

from these amateur photographs which often are of poor quality. We got photographs of any size, pocket size, super 8-film pieces, unsharp or sharp instant photographic pictures, mostly 24 x 36 mm standard format, but quite often also 6 x 6 cm medium format photographs. After about ten years of experience as court experts for photogrammetry and after eight years of development of the computer program system "ORIENT" the authors recommend to centralize the bundle-photogrammetric computation, whereas field survey and measurement of image coordinates as well as handling of the court expertises as a whole should be executed by local surveyor-photogrammetrists. The reason therefore is that an operator continuously working with ORIENT can do his job more efficiently.

2. ORIENT, the software base for traffic accident photogrammetry

Amateur photogrammetry means combined and very generally applied adjustment of bundles, models as well as other geodetic or fictitious data. The theory of the Viennese program system has been published already at the Helsinki Congress (Kager-Kraus, 1976). Details about the command language DIRAN (directive analyzer) and practical results have been reported at the Hamburg Congress (Kager 1980). In the meantime some new modules have been added to the program system, one of which is the graphic module for the graphic output of points with or without line connection, with various point and line symbols. Lettering of the point may concern point number, coordinates or residuals. Windowing and zooming (i.e. scaling of the window area) are possible. The interactive digitizing module includes various updating features such as generating and updating of point numbers individually or incrementally. The directive analyzer DIRAN has learned to interpret command abbreviatons. A name of up to eight alphanumeric characters may replace now symbolically any text in a directive (soft function key). These symbols convert command procedures, already used statically, into dynamically adaptable very versatile processes. The adjustment module has been completed by a Q_{xx} and Q_{vv} facility which computes the standard deviations for each of the unknowns and for each of the residuals respectively.

ORIENT is now a photogrammetric computer language of great versatility, which also students learn to handle within a month's time.

Up to now ORIENT has been installed on the following computers: CDC Cyber 170/172, DEC VAX 11/780, Honeywell Bull Mini 6, HP 1000.

3. The work flow for traffic accident expertises (see appendix):

3.1 The information phase

The expert photogrammetrist receives his mandate normally directly from the court or other court experts, but also from insurance companies or private parties. He studies the pleadings, carefully searching for any metric information in plans, sketches, reports or sworn evidences of witnesses, observing any contradiction or missing metric knowledge. The findings from the existing documents enable him to define his mandate technically, to decide about the further working steps. Mostly some documents are missing, e.g. plans of the vehicles, original negatives, the camera's focal distance, cameratype and lens. Sometimes the camera itself is required for calibration.

3.2 The field survey phase

In the phase of field work preparation he orders full format enlargements of the photographs. Two series are required, one for a complete photo-documentation, the other for his own work.

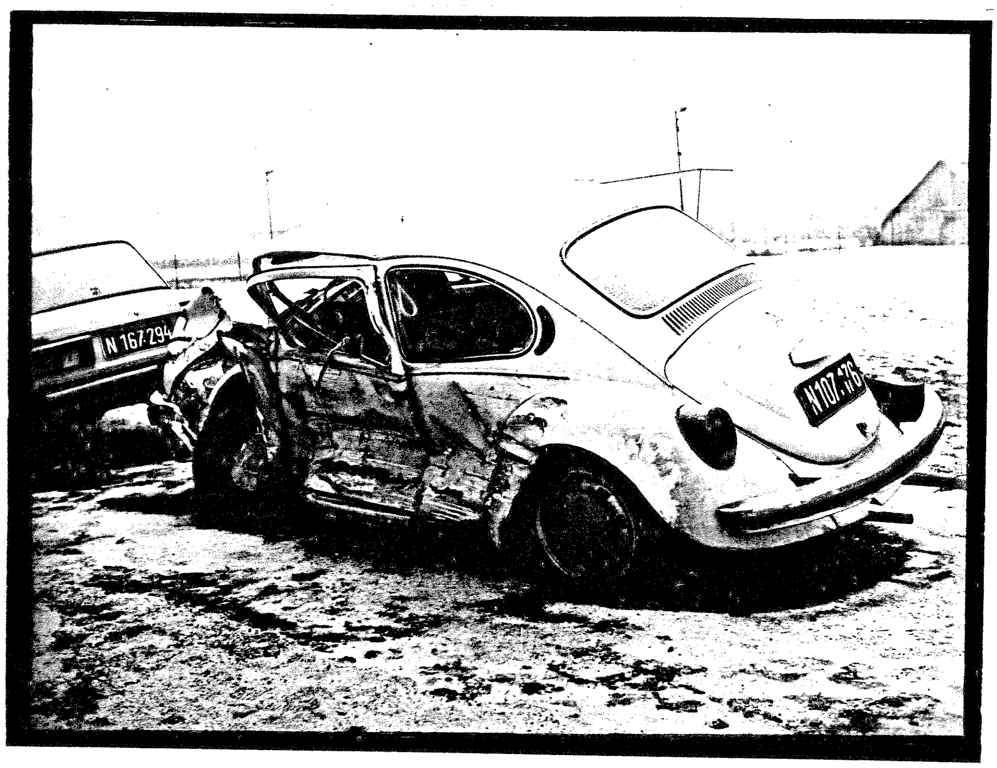

Fig. 1: An traffic accident amateur photograph with the camera's frame for check of completeness as well as for the visibility of the "fiducial corners". Normally three times enlargements are used.

Color negatives have a yellow mask; it is impossible in the most cases to measure them, therefore contact diapositives have to be made. It is always better, more informative and therefore more precise to measure in diapositives instead of negatives.

In approximately 30 % of all cases the photogrammetric problem is so simple that also the well known perspective geometric methods of line - or plane rectification can be used, e.g. when only a distance is asked or when only a specific position has to be determined inbetween of a row of pavement stones. In such cases also the requirements of photographic quality are reduced. Often it is necessary to enhance the contrast of the traces and details in the shadows, or to expose the nearly invisible camera frame of flashed night-photographs differently from the other parts of the picture.

After the availability of restitutable photographs the preparation of the geodetic fieldwork starts with the election of possible ground control and tie points for the bundle block. As to their distribution, it needs only some static-geometric common sense. Of course, the more passpoints the better the reliability.

At the beginning of the field work a rather lengthy and detective search is necessary for adequate points which define a proper and precise connection between bundles and the nature of today. There are too many changes; since the day of accident, one to three or even more years have passed away ! Changes in the field since the day of accident and other remarkable informations, such as scratches found in the asphalt pavement, have to be reported in the field findings.

The geodetic survey includes the selected control points, details of the surroundings (often ± 200 m off the place of accident), longitudinal and cross slopes, curvature of the road and what is called the "gestalts" x). What are these gestalts ? Planes, bended surfaces, which may be represented mathematically by polynomials. E.g. a z-gestalt is a polynomial function of the form $z = f(x,y)$, which may represent a known part of the surface of a street. The kind of coefficients has to be indicated by the field surveyor, the only one, who has seen the surface in the field. It is also him who has to select and measure the control points - mostly tacheometrically and by levelling (to get x, y as well as - more precisely - z) for the later computation of the chosen coefficients. The distribution of ground control must be done appropiately, guaranteeing that each of the coefficients can be determined without any singularity and that the whole of the definition area of the z-gestalt is controlled. An x- or y-gestalt may be a vertical plane or, together with non linear polynomial coefficients, again an arbitrary surface, which defines together with a z-gestalt the intersection line of both, in general a curve, representing e.g. a borderline of a street. In the special case of two linear gestalts a mathematical model is given for a straight line. Of course, each gestalt has also its parameters of absolute orientation, which may be knowns or unknowns.

Thus in general 10 to 100 control points need to be surveyed in the field. The intersection method is needed quite often because many high points have to be determined such as mast tops, branches of trees, roof corners, window crosses, etc. and because of the traffic on the roads. On heavy traffic roads it is recommended to cooperate with the police.

Additional fieldwork is required if also vehicles have to be measured geodetically or by normal case stereomodels. Often it is sufficient to scale off the vehicle coordinates from existing vehicle plans. The so found model, a cloud of points with unknown spatial parameters, will be transformed and adjusted by ORIENT together with the bundles and gestalts. Vehicle models have been necessary for a proper solution of the problem in about 10 percent of the cases treated until now (e.g. the helicopter example in Kager, 1980).

As results of the field survey phase there are available: A plan of the surroundings with estimated positions of the camera stand points and photo directions, the gestalt-definition-areas and their control, a file of block control points and of vehicle-model-points ready for computer input.

3.3 The photogrammetric phase

Photocoordinates can be measured monocularly by any of the analogue instruments with numerical registration. Better of course are comparators or analytical plotters. On the photo carrier more than only one photograph can be placed. At the beginning the frame corners are measured photo by photo

x) Gestalt = shape, figure, form, surface, configuration, structure;
here: plane, surface, straight line, curve.

using a point number, which is a combination of photo number and corner number. The corners may be measured directly or indirectly (Fig. 2).

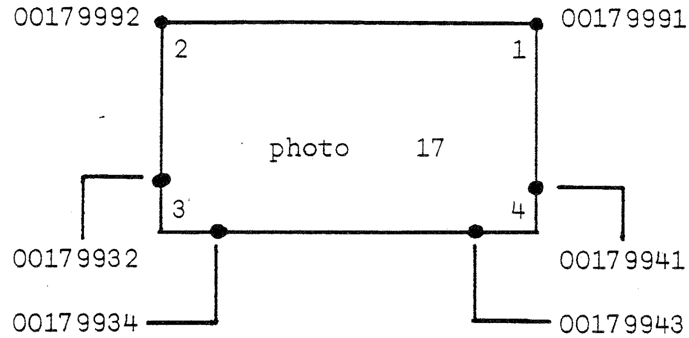

Fig. 2: Numbering of fiducial corners for direct and indirect measurements. (Photo 17, corners 1-4).

That way the computer knows the coordinate areas of the various photos and by a special subroutine he is able to merge any new point to the proper photo file. This is an important feature because correct point identification requires fast and frequent jumping from one photograph to another.

Simultaneously with or immediately after the image coordinate measurements a point occurance matrix, i.e. a survey-list of points, has to be prepared for the ORIENT-operator. It shows, which point number occurs in which photo file, which points are ground control or tie points, which belong to which gestalt, model, trace, or which points are needed for block adjustment and which points are only to be intersected. While setting up this point occurance list the photogrammetric operator checks the completeness of his measurements. Fictitious observations, as for example two points of a vertical mast, which shall have the same (but unknown) xy-position, are also indicated. The same is valid for any other control-relation between points, as distance, slope, azimuth or orthogonality.

Approximate values for the coordinates of the projection centres are not required by ORIENT, but for the rotation matrices ORIENT needs start values. ORIENT gives a lot of help for that to the operator who should know about the approximate viewing direction for each image from the provisional map. Therefore it is advisable to plot also the estimated projection centres on it.

After all the photogrammetrist hands over the following materials to the ORIENT operator:
- the provisional map (1:200 in the most cases) with photo-standpoints (estimated), ground control points, viewing directions, gestalt areas and gestalt numbers;
- the photos, with control and tie points gross marked and numbered;
- a magnetic tape (or other storage medium) with the measurements of image coordinates and a list of corrections, if necessary;
- a magnetic tape (or already a computer file) with the ground control points;
- a list of camera data (camera constant, distortion, fiducial corner coordinates etc., as far as known);
- a list of necessary gestalt coefficients;
- the point occurance matrix;
- a plotting order (range, scale, colours, point numbers).

3.4 The adjustment phase

The ORIENT operator edits the input files, correcting wrong point numbers etc., then he specifies the transformations for the inner orientation and types in the inner orientation data for each or for groups of images. He continues with the computation of the space resection elements for each of the bundles and of the inner orientations. It follow a phase of intersection of tie points (for approximate values) and a common adjustment phase. He defines the gestalts and computes their polynomial parameters, again followed by a common adjustment. He defines the (car-)models and finds the six elements of space orientation for each of the model coordinate systems by a new adjustment, at first approximately among fixed bundles, then again an "everything free" adjustment. The step by step adjustment with automatic gross error indication by maximum normalized residuals helps the operator to easily debug the input data. For the final adjustment all unknown parameters are free and active. The final step concerns the Q_{xx} and Q_{vv}, i.e. the computation of the standard deviation for each of the unknowns and residuals respectively. The ten largest normalized residuals are shown in the adjustment report.

Fig. 3 shows for 15 different and typical cases an extract of the technical results of the adjustment phase as well as the time needed for the ORIENT computations.

case nr.	nr. of photos	nr.of different inner orientations	nr. of gestalts	nr. of models	c [mm]	nr. of observations	nr. of redundant observations	σ_o [µm] in the images	ORIENT computation time [hrs]
1	2	1	4	0	43	987	215	24	6,5
2	3	1	6	0	43	870	215	14	7,0
3	2	1	3	0	45	760	133	19	2,5
4	2	2	2	0	47/105	532	94	21	4,0
5	3	1	2	0	41	565	113	25	3,5
6	4	1	1	0	48	809	111	10	7,0
7	9	1	3	0	48	978	157	22	6,0
8	8	2	3	0	50	1884	272	22	12,0
9	1	1	1	1	56	116	40	63	6,0
10	6	1	3	0	75	1363	247	20	4,0
11	6	2	3	0	28/41	704	215	20	22,0 x)
12	3	3	5	0	45	585	123	18	30,0 x)
13	3	1	3	2	41	474	120	27	10,0
14	3	1	3	0	75	745	141	19	4,0
15	7	1	3	0	75	1028	213	31	7,0

x) instruction

Fig. 3: Results of ORIENT adjustment for 15 different cases of traffic accident amateur bundle blocks.

It can be seen that block sizes ranged from 1-9 photographs, only sometimes of different cameras. Gestalts have been used regularly but vehicle models were rather seldom really needed. The large numbers of ground control points have been measured for the determination of the pavement surfaces and for control curves as asphalt borders or guide lines. The standard deviation σ_o normally was between 10 und 25 µm, only in special cases of bad (or enlarged) photography it was worse. The standard deviations of the object coordinates varied immensely due to their angle of intersection, but the results have been satisfactory in all cases.

The output of ORIENT is a plot e.g. 1:200 with coordinate crosses well fitting to the plot of the geodetic survey together with computer listings, i.e. a computation report and numerical results, mainly the list of coordinates and orientation elements, both with standard deviations.

3.5 To the expertise finishing phase

The photogrammetric expert has to discuss and to defend his results (but not to interprete, this is the traffic-expert's task) and to check on the completeness of his expertise; all questions should have been answered.

4. Economic aspects

During the last four years about 100 court expertises have been treated or supervised by our institute, 75 of which have been computed with ORIENT, alltogether for 8 different court expert surveyors. This shows that the program system ORIENT opens a new field for photogrammetric specialists, a measuring and computation service for a larger group of court expert surveyors.

The total working time for all phases for such court expertises is between 25 to 80 man hours. 40 % of the costs concern the field work, 20 % are needed for photography and photogrammetry, 20 % for the ORIENT computations and for the plotting of the results, the remainder of 20 % is for fair drawing, documentation, the expertise and for other costs as postage, copying etc.

The adjustment process with ORIENT takes 2-10 hours at the computer terminal on the supposition that the previous working phases have been well done. Bad preparation may cause doubling of computation time. Good coordination and organization may well help to further reduce the number of working hours in all phases. An important aspect is that court expertises normally can be done without time pressure within 6-10 weeks; thus it is a gap filling job for the professional field of the surveyors and photogrammetrists. It is an interesting job at least for those who like detective novels. But it is also an instructive job for those who like quick driving or those who don't use the safety belt.

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1. Information

- Receipt and study of files on the trial
- Technical definition of the mandate
- Order of missing documents
- Findings from the files (=: A)

2. Field survey

- Preparation of photography
- Photographic documentation (=: B)
- Photographic findings (=: B)
- Preselection of ground control
- Field inspection and point selection
- Definition of coordinate system
- Definition of gestalts
- Field survey and computation
- Field findings (=: C)
- Plotting and check (=:D)

3. Photogrammetry

- Preselection of tie-points
- Numbering of detail
- Measurement of image coordinates
- Point occurance matrix
- Check for completeness
- Preparation of inner orientation data
- Preparation of outer orientation data

4. Adjustment

- Editing of input file
- Defining of parameters
- Step by step adjustment with ORIENT
- Plotting of results (=: E)

5. Expertise

- Combination of D and E (=: F)
- Conception and fair expertise + A + B + C (=: G)
- Fair drawing of F (=: H)
- Invoice (=: I)
- Return of files + G + H + I

Appendix: The work flow for traffic accident expertises