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Method for Acquiring Building Registry Vector Data with Modern Photogrammetric Techniques

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Abstract. This article presents a methodology for acquiring vector data to supplement building registry databases via a process of integrating surveying data and photogrammetric data using modern measurement tools and methods. The main portion of the article categorizes such a photogrammetric/surveying measurement system developed following this methodology, describing its functionality particularly in respect to the importing and integration of data in the process of adjusting photogrammetric and surveying observations, using the solution of observation equations proposed by authors. The photogrammetric process of obtaining vector data for the use in the building registry, based on stereo measurements performed on models obtained from images taken by the UltraCam-X large-format aerial digital camera and from image sequences obtained from an ADS-40 pushbroom digital aerial camera, have been analysed. Given the increasing importance of photogrammetric measurements in supplying data for building registry databases, the scope of use of such measurements in relation to existing field survey measurements, was considered. The individual stages in the processing of photogrammetric/surveying data using the proposed application developed by the authors within the MicroStation design environment, were presented and discussed. In conclusion it has been stated, that taking the right methodological approach to acquiring such vector data to supplement building registry databases paves the way to establishing a modern cadastral system.

Keywords: photogrammetry, building registry, digital cameras, observation adjustment, data integration

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1. Introduction

Given the necessity to harmonize Poland's surveying regulations with EU standards for developing spatial information systems, including cadastral systems, Poland faces a need to establish a comprehensive system of acquiring and processing building registry data with modern measurement techniques that make use of state-of-the-art geoinformatic tools (Kurczyński, 2002) in addition to direct field surveying measurements. The purpose of such system will be to fully integrate data derived from various measurement sources used in surveying, including photogrammetric data obtained by using modern digital technologies. In Poland, as well as and abroad, the functioning systems used to obtain photogrammetric data for the purposes of the building registry are mainly based on in-house measurement process performed on aerial and satellite digital orthophotomaps (Prudhvi Raju et al., 2008; Suveg and Vosselman, 2002; Weissmann, 2006). At present, such data can also be obtained via the filtration of point clouds from LiDAR aerial laser scanning (Overby et al., 2004; Vosselman et al., 1999). Whereas orthophotomaps involve significant measurement restrictions related to the invisibility of certain building edges and foundations, aerial laser scanning faces a barrier in terms of high processing costs. To hold down the costs and time requirements of establishing a modern building registry base, a priority has been placed in Poland on using photogrammetric data obtained by using advanced aerial digital cameras, of either large-format or scanning type. One circumstance arguing in favour of this approach is the fact that the Polish state surveying service possesses current scanned aerial photographs for the whole area of the country, as well as digital camera photographs for selected regions.

The Photogrammetry Department of the Institute of Geodesy and Cartography in Warsaw has developed an integrated photogrammetric/surveying system for acquiring building registry data, based on the method of supplementing the existing vector databases with data derived from stereoplotting of models based on scanned aerial photographs and photographs from digital cameras. Such data, further supplemented with field survey measurements, constitute a basis for identifying the precise position and shape of buildings in the process of generating registry maps. This methodology aims to reduce the costs and time requirements involved in acquiring and processing data for building registries. Part of this methodological proposal has involved an application, developed by authors, for correcting building roof contours determined by stereoplotting and their reduction to building ground contours, which have supplemented the existing toolset of the ImageStation Intergraph photogrammetric station.

2. System description

The proposed system is concentrated on the integration of building registry data acquired through direct field measurements using surveying methods and data from in-house measurement work performed using photogrammetric methods. The tools and methods of the system allow for:

- importing of surveying data which describe the linear frontal dimension of building grounds and the estimated directional angles of those grounds,
- importing of photogrammetric data which describe the roof contours and segments of the linear building grounds visible on the stereo models based on digital images obtained from the ADS-40 pushbroom scanner camera or UltraCam-X large-format camera,
- the integration of the acquired data using a CAD environment (MicroStation), especially involving the automatic assignment of roof contours to the respective frontal dimensions of building grounds and their identifiers,
- the adjustment of photogrammetric/surveying observations using the author's solution of observation equations,
- user monitoring of the adjustment process,
- exporting of the adjusted observations into the building registry database.

The conceptual scheme of the system is illustrated in Figure 1. System operation involves the use of standard tools for importing input data (photogrammetric and surveying data) and then managing processes aimed at deriving output compatible with the geometric and descriptive structure of the building registry database. The tasks implemented within each of the individual blocks of this system are described below.

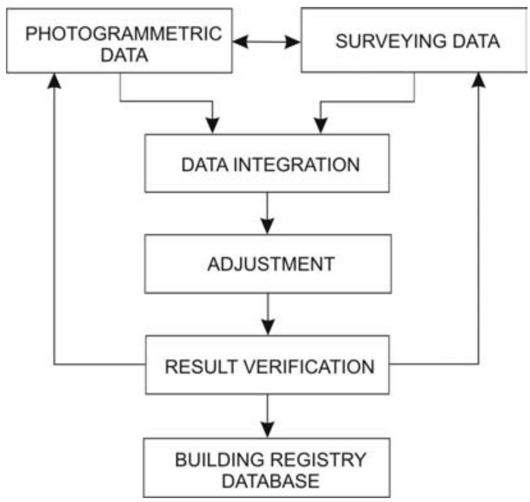

Fig. 1. Conceptual scheme of the photogrammetric/surveying system for acquiring building registry vector data

3. Processing of photogrammetric data

The comprehensive analysis of photogrammetric approaches has indicated that presently the best solution for collection of photogrammetric data in urban areas is stereo digitising of models based on a sequence of ADS-40 images, which enable to measure nearly all building ground contours, thus keeping field measurements limited to a minimum.

It has also been concluded that the best tool for acquiring photogrammetric building registry data is the ImageStation Intergraph photogrammetric workstation, supported with software for processing of stereo models based on images from various camera types. The essential stage of work on acquiring building registry data through photogrammetry was preceded by work on developing a method for correcting the linear and angular elements of the exterior orientation of individual ADS-40 image lines and UltraCam-X image arrays. Selected exterior orientation elements were used to reconstruct the stereo models, for generating measurements of roof contours and visible segments of building grounds. Those measurements were registered in different layers of the MicroStation design space. Such photogrammetric data can be used as the basis to define the extent of necessary field survey measurements, to be submitted to survey teams in the form of a report (Fig. 2).

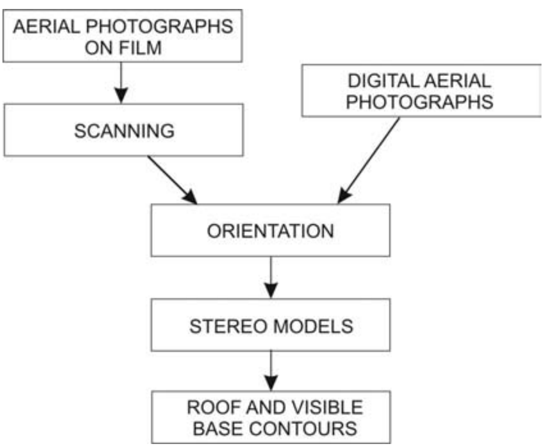

Fig. 2. Scheme of the acquisition of photogrammetric source data

For the process of roof contour stereoplotting, it is important for the results to be saved in a MicroStation design file of the same 2D type in which final data will be edited. Stereoplotting is performed using tools for drawing „Shape" or „Stream line" objects, with the possibility of adjusting the vertical angles to 90°, except in cases when the visible field situation justifies deviation from a right angle for certain roof contour vertices.

In the case of roof edge contours which involve different heights of the individual vertices, the measured height coordinate of the next vertex has to be reduced to the level of the first vertex. Plotting of detached buildings (i.e. not adjacent to other buildings) proceeds clockwise from an arbitrary vertex, „lashing" the contour onto the initial vertex (Fig. 3).

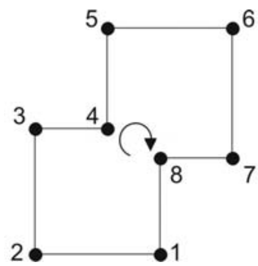

Fig. 3. Plotting of detached buildings

In the next stage of photogrammetric data processing, the spatial orientation of building ground is succeeded plotting of the visible segment of its contour (i.e. the adjusting segment). Plotting starts with a vertex which ensures that measurement proceeds in a clockwise direction (Fig. 4).

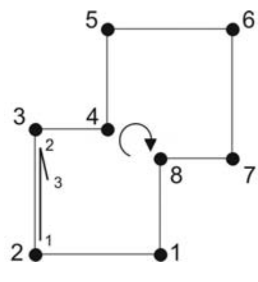

Fig. 4. Plotting of visible segments of building ground contours

Registration of the visible adjusting segment (e.g. segment 1-2) ends at a third vertex (point 3), arbitrarily positioned within the contour. This point is not a carrier of data for ground contour adjustment, but rather serves to mark the adjusting segment during editing. It is important for the registration of such a building ground adjustment segment to be sequenced immediately after the registration of the roof contours. For a group of two or more buildings that are adjacent along at least two-point ground segments (as adjacency of roof contours does not always imply adjacency of building grounds), we proceed with plotting by starting from the primary building, which is taken to be the building with the best (i.e. the longest and possibly the most visible) adjustment segments. Note that in a group of closely related buildings, not all buildings will necessarily have their own building ground adjustment segments. Single-point adjustment is permitted if the second adjustment vertex is poorly visible or completely invisible.

In Figure 5, the example of the measuring situation is illustrated. It is advantageous to start the measurement from the roof contour of building 4, followed by the ground building adjustment segment 1 - 2 (the longest in the group), then proceeding with the roof contour of building 1 and its ground adjustment segment, and then the roof contour of building 3 and the roof contour of building 2, together with the single-point ground adjustment segment of building 2 (building 3 lacks any adjustment segment).

The colour of the roof contours of residential buildings should be distinguished from that of non-residential buildings. When launching the proposed program, red was used for residential buildings, green for nonresidential buildings, and blue for adjustment segments. The stereo plotting results should be saved into layer 1 of the MicroStation design file.

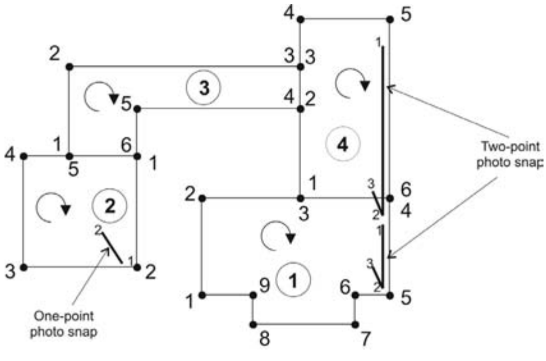

Fig. 5. Plotting of a group of buildings

Adjacent building roof contours form a network of closed figures, precisely linked at vertex points.

When stereo plotting of all visible buildings within the first district had been completed, and the completeness and correctness of the „lashing" of individual buildings within the groups have been verified, the 3D MicroStation design file should be exported into 2D graphic type file. After that the stereo plotting work within the next district can be executed. The 2D design file so generated is transferred to the editing workstation also equipped with MicroStation software.

4. Processing of surveying data

Field survey measurements taken to supplement the results of photogrammetric work are registered in the system via a Microsoft Access database, which enables them to be transformed into a tabular text file. A survey team assigns an identifier to each building measured, comprised of the number of the district, the address number of the settlement, and the number of the building within the given settlement, and also assigns numbers to the vertex points of the building and relates these to the basic measurement data in the form of a right angle or frontal dimension (Fig. 6).

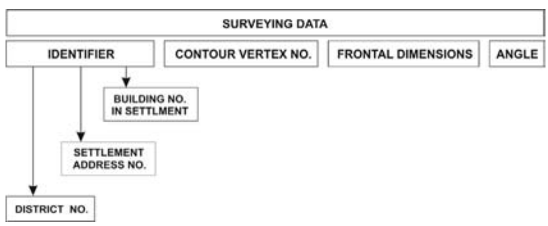

Fig. 6. The set of surveying data

All measurements proceed following a clockwise direction. Information obtained in the field is then compared against the photogrammetric sketches.

Based on working printouts of building roof contours, the field team first of all identifies the settlement, then the unique address numbers to the individual buildings are annotated and entered into the sketches in a way that ensures their unambiguous association with the correct roof contours. The address number assigned to a given building is a series of graphical characters comprised of three parts separated by a „space" character, with the first denoting the number of the district, the second the address number of the settlement, and the third the building number within the given settlement.

Utilizing the building ground adjustment segments entered into the printouts, the ground contours of individual buildings in a settlement are sketched, taking account of any adjacent segments identified in the field. In the next stage, the vertices of the ground contours of individual detached buildings and groups of buildings are assigned to unique numbers. Here we should stress that the numbering order of ground contours for detached buildings differs from the numbering order for groups of buildings. The contour vertices for an individual detached building are numbered starting from the first point of the ground adjustment segment; subsequent vertices are successively numbered in the clockwise direction (Fig. 7).

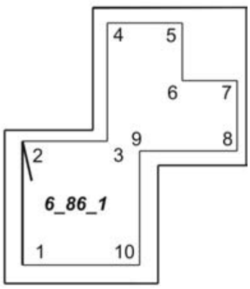

Fig. 7. Numbering of vertices for detached buildings

The numbering of vertices of related building ground contours within groups of buildings is illustrated in Figure 8. Each vertex receives a unique number within the group, ranging from 1 to n, starting with the first vertex of the primary ground contour adjustment segment (marked by photogrammetry with a thicker line). This vertex receives the first number, followed by other vertices successively numbered proceeding in a clockwise direction, until the last vertex of the primary contour is numbered.

The numbering of vertices then proceeds with the next ground contour adjacent to the primary contour, skipping vertices of the ground contour which have already received unique numbers within the group, following the principle that numbering must proceed in the clockwise direction. Successive adjacent contours are considered proceeding from the lowest already assigned vertex number upward, until all the contours in the group have been assigned vertex numbers.

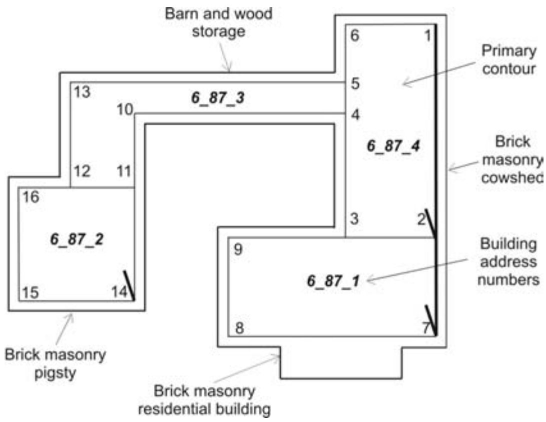

Fig. 8. Numbering of vertices of linked building ground contours

It is important for each vertex to be numbered, whether it is part of an individual contour or a group of contours. Moreover, this numbering must be unique, continuous, and increasing.

After all vertices on the sketch have been numbered, the distances between the numbered vertices of the building ground contour and the rightward angles at the vertices are measured or estimated (proceeding along the contour in a clockwise direction). The results are registered in a handheld registering device with a properly configured Microsoft Access database, using the assigned numbers of buildings and vertices. Measurements are taken in the same order as the vertices are numbered on the sketch, following „default" prompts from the Access database, which helps avoid any possible skipping of measurements or mistakes in registration when working with more complex shapes and ground contours linked into groups.

The general rule in the case of groups of contours is to begin measurements from the first vertex of the primary contour, proceeding to the last. For successive contours within a group, the same rule is followed as for assigning numbers on the sketches. Measurements are taken and recorded for each successive vertex as follows: first a full identification of the vertex is entered using the prompts supplied (consisting of the address number of the contour and the unique vertex number within the group), then the measured or estimated length of the segment between the current vertex and the next vertex in the contour is entered, followed by the estimated value of the rightward angle measured in degrees at the current vertex, between the rays leading to the previous and subsequent vertices in the given contour. The record of these measurements for the current vertex is then stored in the Microsoft Access database. The syntax of the measurement (or estimation) result record is illustrated in Figure 9 for an example vertex of a primary contour.

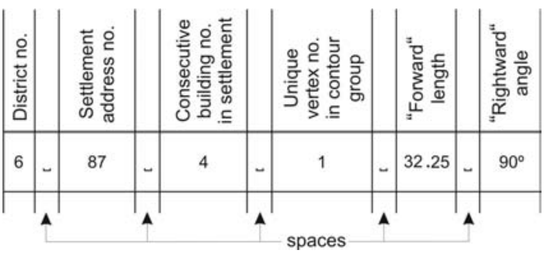

Fig. 9. Syntax of a measurement result record for a vertex of a primary contour

Certain conventions were adopted for recording measurement or estimation values for lengths/angles in the Access database (or ASCII file). For lengths the conventions were as follows:

– a length stated with two decimal places indicates the value was measured with a surveying device with an accuracy of 0.03 m,
– a length stated with one decimal place indicates the value was calculated with an accuracy of 0.3 m, based on other certain lengths directly measured or calculated on the basis of explicit geometric or structural considerations,
– a length stated as a whole number together with a final decimal point indicates that the value was estimated with an accuracy of 1 m, based on other estimated lengths or on the basis of uncertain geometric considerations,
– a length stated as a whole number without a final decimal point indicates that the value was estimated with an accuracy no better than 3 m, due to complete inaccessibility for the purposes of measurement or due to a lack of certain geometric or structural considerations.

For angles the conventions were as follows:

– an angle stated with one decimal place indicates that the value was measured using an analogue angular device with an accuracy of 0.3°,
– an angle stated as an integer number value together with a final decimal point indicates that the value was estimated with an accuracy of 1°, based on certain geometric considerations supported by the structural and on-site situation,
– an angle stated as a whole number without a final decimal point indicates that the value was estimated as a considerable approximation, with an accuracy of 3°, without confirmation of the on-site situation or structural considerations.

The set of successive records containing measurement results for all the vertices of one building ground contour may be treated as a measurement dataset for a polygonal traverse, linked to the network at two points (the points of the adjustment segment), defined with respect to the prevailing coordinate system. This traverse may include values measured with precision in excess of the requirements of the building registry database, or values falling significantly below those accuracy requirements in terms of both the modelling of the contour shapes and their positioning and orientation. However, the importance of using lower-accuracy data cannot be overestimated when they become factors limiting the indeterminability of unknowns at transition stages in seeking final values for unknown coordinates of building ground vertices, relative to the prevailing coordinate system used in the building registry. More even balancing of the precision of determinants is achieved through the simultaneous adjustment of data from building ground contour measurements and photogrammetric data from roof contour measurements and multiple fittings of the ground contours, something that is particularly important for groups of contours.

The issues described above are illustrated in Table 1, which presents a consistent elaboration of data the records for the theoretical case illustrated in Figure 9.

Table 1. Data records containing measurements in the Microsoft Access database

district no.	settlement address no.	building no. in settlement	unique vertex no.	„forward" length	„rightward" angle
6	87	4	1	32.25	90
6	87	4	2	8.5	90
6	87	4	3	20.30	90
6	87	4	4	8	180
6	87	4	5	4.00	180
6	87	4	6	8.55	90
6	87	1	2	10.22	90
6	87	1	7	21.05	90
6	87	1	8	10.20	90
6	87	1	9	12.55	90
6	87	1	3	8.5	180
6	87	3	4	12.40	90
6	87	3	10	9.75	270
6	87	3	11	8	90
6	87	3	12	18.53	90
6	87	3	13	20.50	90
6	87	3	5	8	90
6	87	2	11	20.70	90
6	87	2	14	15.33	90
6	87	2	15	20.75	90
6	87	2	16	17.30	90
6	87	2	16	8	180
Default indicators supplied by Access – may be modified				Measurement/ estimation results, entered on an ongoing basis	

After sketches are made and the measurement (estimation) of all the building ground contours has been completed within the given district or significant portion thereof (if it is appropriate for processing of a district to be divided into stages), both the sketches and the Access database / ASCII file content are referred back to the photogrammetric team to continue editing the content of the MicroStation design file.

5. Integration of measurement data using the proposed algorithm

Using the Visual Basic programming language and MicroStation modules, an algorithm enabling photogrammetric data recorded in a DGN file to be integrated with field data recorded in a Microsoft Access database was developed. The integration method proceeds by assigning identifiers to the roof contours obtained through stereo plotting; these identifiers are assigned to buildings by survey teams during field measurements. The assigning of descriptive data to graphical data gives rise to a list of „tags" in the MicroStation program, used by our algorithm.

Our algorithm also follows a methodology of adjusting photogrammetric and field survey data based on the successive creation of normal equations for individual observations related to a given building vertex point. Our procedure of adjusting observations for a given vertex point generates from two to five observation equations: two of these equations relate to the surveying measurements of building ground contours, another two relate to photogrammetrically measured contours, while the last describes the orientation of the side of the generalized roof contour segment. The adjustment process assigns a weight to each observation (the standard deviation of that observation). The adjustment algorithm is based on the least-squares method and on identifying the error of the unknown coordinates of ground contour apex points and the standard deviation of a typical observation of weight 1.

Our original program operating in the MicroStation environment proceeds through the following stages of processing survey and photogrammetric data:

– reading in, from the DGN design file, the non-geometric data assigned to the building roof contours which have been selected for reduction to ground contours,
– adding survey data found in the ASC format text file of the Access database,
– assigning measurements from the ASC text file to the objects from the DGN file, identifying the RMSE of the individual values,

- reading in, from the photogrammetric data, the coordinates of the roof contour vertices, then organizing them in the form of schematic models and identifying the standard deviation of the values saved as observations in working tables, facilitating the generation of correction equations for photogrammetric observations and adjustment segments as closed traverses, with scattered non-closure deviations (the corrections to these values are the unknowns in the system of correction equations for surveying observations and adjustment segments, described above),
- generating successive tables of the system of correction equations,
- generating the overall system of correction equations for surveying observations, photogrammetric observations, and adjustment segments, balancing the individual observations by dividing the equations by the standard deviation of those observations,
- solving the set of normal equations using the least-squares method, correcting the approximate coordinate values of the ground contour vertices by estimating the RMSE of the unknowns (the coordinates of the ground contour vertices and the standard deviation of an observation of weight 1).
- displaying the modelled ground contours inside the corresponding roof contours in order to verify the correctness of the adjustments, allowing for changes in view window parameters for the settlement area being edited,
- allowing the user to make a final verification decision,
- completing the given stage of the modelling work and reverting to a status from which the next building or group can be edited.

The overall set of correction equations for surveying observations, photogrammetric observations, and adjustment segments is generated successively, for successive ground contours. For each ground contour considered, the equations are generated in repeatable groups related to the successive vertices of the contour. This elementary group of equations related to the successively considered contour vertex may contain from two to seven observation equations, depending on the number and type of observations assigned to that vertex. In general there are two correction equations for surveying observations of the building ground, two correction equations for observations of the adjustment segments, and one equation for the block orientation of the properly generalized roof contour segment.

Figure 10 shows the basic vector arrangement between three neighbouring vertices of the ground contour, where vertex *C* (central) is the „current" vertex of the contour, vertex *P* (front) is the „*C*+1" vertex, and vertex *T* (rear) is the „*C*–1" vertex.

Here two special cases are distinguished for a sample n-vertex contour: In the first *C* is the 1st vertex while *T* is the n-th vertex, and in the second *C* is the n-th vertex while *P* is the 1st vertex.

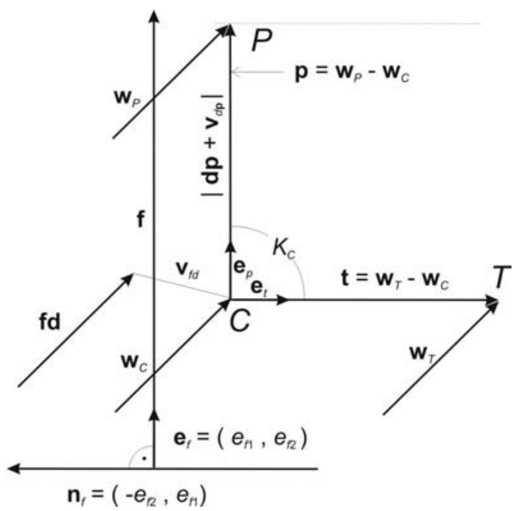

Fig. 10. Basic vector arrangement of ground contour vertices

In Figure 10:

- $\mathbf{w}_T$, $\mathbf{w}_C$, $\mathbf{w}_P$ are the position vectors (in the prevailing reference system used in the building registry) of vertices *T*, *C*, *P* in the roof contour, whose *X*, *Y* coordinates represent the unknowns to be set by adjustment. The variables are approximate values $\mathbf{w}_{0T}$, $\mathbf{w}_{0C}$ and $\mathbf{w}_{0P}$ for which the following dependencies hold: $\mathbf{w}_T = \mathbf{w}_{0T} + \mathbf{dw}_T$; $\mathbf{w}_C = \mathbf{w}_{0C} + \mathbf{dw}_C$; $\mathbf{w}_P = \mathbf{w}_{0P} + \mathbf{dw}_P$ whereby $\mathbf{dw}_T$,

$\mathbf{dw}_C$, $\mathbf{dw}_P$ represent vectors of the corrections to the approximate values of the intermediary unknowns;
- **fd**, v_{fd} are fitting vector for vertex *C* and its minimized adjustment correction;
- **f** is the vector of the generalized roof contour segment, with a direction preliminarily verified and consistent with the direction of the vector $\mathbf{p} = \mathbf{w}_p - \mathbf{w}_c$ calculated on the basis of known approximate values $\mathbf{w}_{0P}$ and $\mathbf{w}_{0C}$;
- $\mathbf{e}_f = (e_{f1}, e_{f2})$ represents the unit (directional) vector for the vector **f** and its coordinates;
- $\mathbf{n}_f = (-e_{f1}, e_{f2})$ represents the „normal" unit vector for the vector **f** and its coordinates;
- $\mathbf{p} = (p_x, p_y) = (w_{Px} - w_{Cx}, w_{Pv} - w_{Cy})$ are the vectors spanned on the vertices *T, C*, and *P* of the two neighbouring segments of the ground contour; to the vector **p** is related the length *dp* of segment *CP* measured in the field, for which the following dependency applies

$$|\mathbf{p}| = dp + v_{dp} \tag{1}$$

where v_{dp} is the adjustment correction of the measured length.

The pair *t*, *p*, as the rays forming the vertex *C*, are related to the field-estimated angle „K_C". For this pair the following dependency for angles close to 90° applies

$$\mathbf{p} \cdot \mathbf{e}_t = |\mathbf{p}| \cdot \cos K_C - |\mathbf{p}| \cdot v_{K_C} \tag{2}$$

where v_{K_C} is the minimized adjustment correction of the estimated angle, and $\mathbf{e}_t$, $\mathbf{e}_p$ are unit (directional) vectors of **t** and **p**.

The basic equation determining the internal precision of the ground contour is the correction equation for the length of the contour segment as an observation and the *X*, *Y* coordinates limiting its two vertices as unknowns derived from the expansion of equation (1) into a series

$$v_{dp} = \frac{p_{0x}}{|\mathbf{p}_0|} \cdot dw_{Px} + \frac{p_{0y}}{|\mathbf{p}_0|} \cdot dw_{Py} - \frac{p_{0x}}{|\mathbf{p}_0|} \cdot dw_{Cx} - \frac{p_{0y}}{|\mathbf{p}_0|} \cdot dw_{Cy} + |\mathbf{p}_0| - dp \tag{3}$$

In the above equation, the index „0" marks values calculated on the basis of approximate values of unknown coordinates of contour vertices. Equation (3), after linearization, is a simplified version based on the scalar product of vectors forming the angle, which can successfully take the place of the classical angle observation equation. After linearization and re-arranging, this equation takes the following form

$$\begin{aligned} dp \cdot v_{K_C} = {} & \frac{t_{0x}}{|\mathbf{t}_0|} \cdot dw_{Px} + \frac{t_{0y}}{|\mathbf{t}_0|} \cdot dw_{Py} \\ & + \left(\frac{p_{0x}}{|\mathbf{t}_0|} - \frac{t_{0x}}{|\mathbf{t}_0|} \cdot \frac{\mathbf{p}_0 \cdot \mathbf{t}_0}{|\mathbf{t}_0|^2} \right) \cdot dw_{Tx} \\ & + \left(\frac{p_{0y}}{|\mathbf{t}_0|} - \frac{t_{0y}}{|\mathbf{t}_0|} \cdot \frac{\mathbf{p}_0 \cdot \mathbf{t}_0}{|\mathbf{t}_0|^2} \right) \cdot dw_{Ty} \\ & - \left(\frac{p_{0x}}{|\mathbf{t}_0|} + \frac{t_{0x}}{|\mathbf{t}_0|} \cdot \left(1 - \frac{\mathbf{p}_0 \cdot \mathbf{t}_0}{|\mathbf{t}_0|^2} \right) \right) \cdot dw_{Cx} \\ & - \left(\frac{p_{0y}}{|\mathbf{t}_0|} + \frac{t_{0y}}{|\mathbf{t}_0|} \cdot \left(1 - \frac{\mathbf{p}_0 \cdot \mathbf{t}_0}{|\mathbf{t}_0|^2} \right) \right) \cdot dw_{Cy} \\ & + \frac{\mathbf{p}_0 \cdot \mathbf{t}_0}{|\mathbf{t}_0|} - dp \cdot \cos K_C \end{aligned} \tag{4}$$

or the following form, further simplified in view of the iterative process of forming and solving systems of correction equations

$$\begin{aligned} dp \cdot v_{K_C} = {} & \frac{t_{0x}}{|\mathbf{t}_0|} \cdot dw_{Px} + \frac{t_{0y}}{|\mathbf{t}_0|} \cdot dw_{Py} \\ & + \frac{p_{0x}}{|\mathbf{t}_0|} \cdot dw_{Tx} + \frac{p_{0y}}{|\mathbf{t}_0|} \cdot dw_{Ty} \\ & - \left(\frac{p_{0x}}{|\mathbf{t}_0|} + \frac{t_{0x}}{|\mathbf{t}_0|} \right) \cdot dw_{Cx} \\ & - \left(\frac{p_{0y}}{|\mathbf{t}_0|} + \frac{t_{0y}}{|\mathbf{t}_0|} \right) \cdot dw_{Cy} \\ & + \frac{\mathbf{p}_0 \cdot \mathbf{t}_0}{|\mathbf{t}_0|} - dp \cdot \cos K_C \end{aligned} \tag{5}$$

Another correction equation that has a significant impact on the shape of the ground contour is the equation of unit (directional) vectors of the corresponding segments of the ground contour and roof contour. This equation takes the form

$$\mathbf{e}_f + \mathbf{v}_{e_f} = \frac{\mathbf{p}}{|\mathbf{p}|} \qquad (6)$$

or after linearization:

$$\begin{aligned} v_e = & \left(\left(-e_{f2} - e_{0px} \cdot \left(\mathbf{e}_{0p} \cdot \mathbf{n}_{e_f}\right)\right)/|\mathbf{p}_0|\right) \cdot dw_{Px} \\ & + \left(\left(e_{f1} - e_{0py} \cdot \left(\mathbf{e}_{0p} \cdot \mathbf{n}_{e_f}\right)\right)/|\mathbf{p}_0|\right) \cdot dw_{Py} \\ & + \left(\left(e_{f2} + e_{0px} \cdot \left(\mathbf{e}_{0p} \cdot \mathbf{n}_{e_f}\right)\right)/|\mathbf{p}_0|\right) \cdot dx_{Cx} \\ & + \left(\left(-e_{f1} + e_{0py} \cdot \left(\mathbf{e}_{0p} \cdot \mathbf{n}_{e_f}\right)\right)/|\mathbf{p}_0|\right) \cdot dx_{Cy} \\ & + \left(\mathbf{e}_{0p} \cdot \mathbf{n}_{e_f}\right) \end{aligned} \qquad (7)$$

The final type of equation consists of photo conjunction correction equations, which have a decisive impact on the positioning and orientation of the building ground with respect to the prevailing reference system used in the building registry. Following simple linearization, these equations take the following form

$$\begin{aligned} v_{fd_x} &= dw_{Cx} + w_{0Cx} - fd_x \\ v_{fd_y} &= dw_{Cy} + w_{0Cy} - fd_y \end{aligned} \qquad (8)$$

The algorithm for generating and solving the system of normal equations and evaluating the accuracy of results was developed based on (3), (5), (7) and (8) the system of correction equations, in which the standard deviation of observations were divided by values set *a priori* for each observation or group of observations. The system of normal equations was resolved fulfilling the criterion $[pvv]$ = min.

Via the procedure of generating and solving normal equations based on the least-squares method, the rms errors of the unknown coordinates are calculated for the ground contour vertices

$$m_0 = \pm\sqrt{[pvv]/(l_{rp} - l_{nw})} \qquad (9)$$

where l_{rp} is the number of correction equations, and l_{nw} - the number of unknowns.

In order to verify the results obtained, within the system developed, a procedure to enable the adjustment process to be user-monitored as it progresses was elaborated. The system also allows for user analysis of adjustment results in the MicroStation program window. Because of the blockage of the MicroStation program functions allowing the display view to be manipulated while the original algorithm is operating, it became necessary to develop an additional procedure to facilitate the visual control of the adjusted ground contours in a MicroStation program window. The decision-making functions of the photogrammetric/surveying system identify the quality of the output product and approve it for entry into the building registry database. In the case of a negative decision, the system informs the user of the need to redefine the source data in order to eliminate gross errors (mistakes).

The final block of the system is a local building registry database, which allows for the exporting of the results obtained into a text file containing a building identifier plus the coordinates of its vertex points, as well as for the generation of a building registry vector map.

6. Conclusions

The system developed was tested using image data from Germany obtained with an ADS-40 digital aerial camera, whereby terrain data was assimilated. Use of the system achieved a maximum deviation of the adjusted building ground contour from the assimilated contour of no more than 3 cm.

Using data from advanced digital aerial cameras to enhance building registry databases can help reduce field survey work to a minimum. In view of the technology of taking digital aerial photographs and their geometric quality, such photographs are becoming the fundamental measurement tool fin the process of generating and updating building registry databases.

The photogrammetric/surveying measurement system that has been presented herein allows building registry databases to be remotely updated using the advanced tools of modern photogrammetry, and also allows for the possibility of update and modification in view of the guidelines of the EU directive INSPIRE.

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References

Kurczyński Z., (2002): *Modernizacja ewidencji gruntów i budynków na terenach gdzie funkcjonują mapy ewidencyjne w skali 1:2880 z wykorzystaniem metod fotogrametrii cyfrowej,* Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. 12b, pp. 203-215.

Overby J., Bodum L., Kjems E., Ilsoe P.M., (2004): *Automatic 3D building reconstruction from airborne laser scanning and cadastral data using Hough transform*, International Archives of Photogrammetry and Remote Sensing, Vol. XXXV, part B3.

Prudhvi Raju K.N., Sarvajeet K., Kshitij M., Manish K.P., (2008): *Urban cadastral mapping using very high resolution remote sensing data*, Journal of the Indian Society of Remote Sensing, pp. 283-288.

Suveg I., Vosselman G., (2002): *Localization and generation of building models*, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 34, part 3A, pp. 356-361.

Vosselman G., (1999): *Building reconstruction using planar faces in very high density height data,* International Archives of Photogrammetry and Remote Sensing, Vol. 32, part 3-2W5, pp. 87-92.

Weissmann K., (2006): *Photogrammetry applied to cadastral survey in Switzerland*, The Photogrammetric Record, Vol. 7, Issue 37, pp. 5-15.

Metodyka pozyskiwania danych wektorowych ewidencji budynków w świetle współczesnych fotogrametrycznych technik pomiarowych

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Streszczenie. W artykule przedstawiono metodykę zasilania bazy danych ewidencji budynków pozyskiwanych w procesie integracji pomiarów geodezyjnych i fotogrametrycznych realizowanych z wykorzystaniem współczesnych narzędzi i metod pomiarowych. W ramach niniejszej metodyki został opracowany geodezyjno-fotogrametryczny system pomiarowy, którego charakterystyka stanowi zasadniczą treść artykułu. Opisana została funkcjonalność tego systemu ze szczególnym uwzględnieniem importu danych oraz ich integracji w procesie wyrównania obserwacji geodezyjnych i fotogrametrycznych z wykorzystaniem autorskiego rozwiązania równań poprawek. Przeprowadzono analizę procesu fotogrametrycznego pozyskiwania danych wektorowych dla potrzeb ewidencji budynków na podstawie pomiarów stereoskopowych na modelach zdjęć pochodzących z wielkoformatowej lotniczej kamery cyfrowej UltraCam-X oraz modelach utworzonych z sekwencji obrazowych pozyskanych lotniczą kamerą skanerową ADS-40. Wobec rosnącej roli pomiarów fotogrametrycznych w procesie zasilania baz danych ewidencji budynków określono zakres ich wykorzystania w stosunku do obowiązujących dotychczas geodezyjnych pomiarów terenowych.
W niniejszym artykule scharakteryzowane zostały poszczególne etapy opracowania danych fotogrametrycznych i geodezyjnych z wykorzystaniem autorskiej aplikacji działającej w środowisku projektowym MicroStation. Stwierdzono, że odpowiednie działania metodyczne w zakresie pozyskiwania danych wektorowych dla potrzeb ewidencji budynków stanowią podstawę nowoczesnego systemu katastralnego.

Słowa kluczowe: fotogrametria, ewidencja budynków, kamery cyfrowe, wyrównanie obserwacji, integracja danych