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Experience from the Utilisation of Archival Aerial Images for the Needs of Databases Feeding**

1. Introduction

We have been watching for several years more and more frequent attempts in Poland to utilise archival photogrammetric materials for various purposes. This is mainly due to the fact that the Army Geographic Board handed over part of its resources to the Central Office of Geodesic and Cartographic Documentation in Warsaw. Photogrammetric materials in the form of archival aerial images find a wider and wider application. The demand of various spatial information system users for archival materials grows continuously. Supplementing databases with orthophotomaps, digital terrain models or other materials, of not necessarily a current nature, is therefore becoming more and more popular, and has its merits. Such information, when stored, can yield numerous benefits, and such materials can be used for various purposes, ranging from the determination of nature and size of environmental changes, through comparison of changes in urban development, to the assessment of war damages and losses. That last mode of application has recently been given a practical aspect in the course of the assessment of losses suffered by the city of Warsaw during World War II. The "orthophotomap of the damaged Warsaw" was then prepared. That study resulted from the resolution adopted by the City Council of Warsaw in April 2004 on the commencement of works aimed at assessing losses suffered by the city and its population during World War II. To that effect, archival aerial photos, made by Soviet pilots in 1945, were utilised. It was decided that the orthophotomap would be prepared based on

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ca. 650 such photographs that were available. The ready product can be seen on the Web page of the City Office of Warsaw. The said project served as an inspiration for developing a broader technology of utilising the archival materials.

The research project presented herein includes developing the technology of utilising archival aerial images as an element of databases feeding.

The goal of such studies is, first of all, restoring the existing condition (orthophotomap, 3D models) of facilities (areas) under consideration in relation to a freely-selected time period provided, of course, that we have the relevant photogrammetric data (e.g. aerial images). Such a proceeding can give a certain outlook on infrastructure of the period, for example it makes it possible to assess the condition of building structures of that time, thus allowing to determine (of course, with a certain degree of approximation only) e.g. expenditures incurred on changing the condition of those building structures within the specified period of time. Those data (aerial images) can be supplemented with ground photos, which approach enables to reconstruct objects, which can show the past days with quite a high accuracy and reliability.

Archival aerial images were utilised in many fields, not only in qualitative analyses of areas that were based on photointerpretation of stereoscopic models, but also in quantitative analyses [8]. Measurements performed on multi-temporal aerial data were utilised to compare geometric changes in land surface that were revealed in specific time intervals [1, 3–5]. Other applications of archival aerial photos include without limitation analyses of changes in urbanised areas, or agricultural areas [7], or coast line changes.

2. Technology

Works performed hereunder included the development of technology, which enables the utilisation of archival photogrammetric materials.

The following stages of that technology were distinguished:

- acquiring the archival materials (mainly aerial photos);
- reconstructing information on orientation elements of those photos;
- processing photos to receive the relevant formats (photographic mosaics, orthophotomaps, 3D models);
- supplementing the existing materials with additional data (e.g. ground photos);
- feeding of databases.

2.1. Acquiring the Archival Materials (Mainly Aerial Photos)

There are two large centres in Poland, which have very rich resources of archival aerial images. The main institution, in which such archival materials are stored, is Central Office of Geodesic and Cartographic Documentation in Warsaw. Recently, the Office received considerable amounts of materials from military archives (handed over by the Army Geography Board). Also, a large number of aerial photos were donated to the Office by former state geodetic enterprise PPGK Warszawa, which once used to have one of major photogrammetric teams in Poland (with several planes and specialised crews).

The second, major resource of archival data is that of Central Military Archives in Rembertów near Warsaw. Their collection contains the most interesting, and at the same time the oldest, historical aerial images. Unfortunately, despite the fact that the resources are really good and abundant (including, among other things, the post-war images of Krakow), it has not been possible so far to acquire them, since the army does not catalogue them, and consequently, does not make them available. Yet, information that could be obtained confirms that there are aerial images of Kraków there, dating back to 1956 and made in the scale of 1:8000. Still, they are kept in military archives and cannot be acquired as at the present day.

Archival aerial images constitute a valuable source of information for specialists in environment protection and monitoring. That is why collections of such data are so highly valued by them.

As far as the Tatra National Park (TPN) area is concerned, aerial photos were made in 1955 (supplemented in 1956), in 1965, 1974, 1977, 1986, 1994, and in 1999.

As far, as the Słowiński National Park (SNP) area is concerned, aerial photos were made in 1951, 1964, 1975, 1984, and in 1997.

2.2. Reconstructing Information on Orientation Elements of Photos

The basic problem in the study of archival aerial images is the lack of information on their internal orientation elements (coordinates of the main point, coordinates of background marks, and the camera constant). Even if one manages to acquire the relevant photos, one will not have, apart from the photos themselves, any other ancillary information on them (fly mission plan, or the camera's certificate are missing).

The process of actual handling of aerial photos needs to be preceded with a proper stage devoted to the preparation of the necessary data. Background mark coordinates can be restored in an analytic way. If we have analogue materials, it is possible to measure background marks on selected images, using an analytical au-

tograph, and then to average them. The so-calculated coordinates may be used for the purpose of image orientation.

In the case of digital materials, coordinates of background marks in pixel arrangement have to be measured, and then multiplied by the pixel size (as expressed in mm). This will make it possible to go further to the metric system (background arrangement expressed in mm). As far as the foregoing projects are concerned, background marks were measured in relation to the first, the last and one of the middle images in a given series. The obtained results amounted to one pixel (the average error of point location after interior orientation).

As far as analogue photos are concerned, the camera constant is, as a rule, recorded on the image itself. If not, it will be necessary to determine the camera type and year in which photos were made. The majority of cameras were calibrated in the Department of Photogrammetry and Remote Sensing Informatics, University of Science and Technology in Krakow, where a large collection of camera calibration data is stored. In the event that no such information is available, the camera constant may be determined in an analytic way. The accuracy of manual measurement results (archival photos) and those of automatic measurement, both relating to the exemplary TPN project, were compared and shown in table 1.

Table 1. Comparison of background mark measurements

Manual measurement, DEPHOS station		Automatic measurement, Interior orientation software	
RMS	0.2498 pix	RMS	0.2477 pix
constant deviation	0.1177 pix	constant deviation	0.1329 pix
maximum	0.586 pix	maximum	0.668 pix
minimum	0.015 pix	minimum	0.029 pix

Therefore, it is possible to restore the coordinates of background marks and the camera constant, whereas the main point location on the photo cannot be restored. In the prevailing number of cases, that point value approximates zero. Differences, if any, can be corrected through aerotriangulation. Modern software includes an option of using the so-called additional parameters in the course of aerotriangulation. This is effected in the process of self-calibration (Inpho software offers a possibility of 22 or 44 parameters that can be used).

2.3. Processing Photos to Receive the Relevant Formats (Photographic Mosaics, Orthophotomaps, 3D Models)

The first step in the case of archival photos is to restore the existing condition of the acquired materials. One of basic, rather simple photogrammetric products to be applied is the photographic mosaic. Figure 4 (p. 78) shows an exemplary

photographic mosaic of the Tatra National Park area, prepared for a set of photos, which were made in 1974. Such photographic mosaic can be prepared with the use of software that allows operating on half-tone screen layers. In addition to image location, the said photographic mosaic contains, most often, information on the distribution of photo points, which makes it possible to easily check, which images include the photo points selected. This also allows easy calculating the approximated coordinates of projection centres (this is indispensable in the case of certain software, e.g. Match-AT by Inpho).

Once the photographic mosaic has been duly prepared, it is necessary to perform the aerotriangulation. The problem faced at that stage concerns the change in the location of current objects in relation to that in the period under consideration. The best way to solve the problem is to acquire other materials from the same period (archival maps, orthophotomaps). The said mosaic (Fig. 4) shows photo points measured with the GPS technology, as well as those read from archival topographic maps. No doubt that the accuracy of coordinates read from the map cannot be compared to that actually measured. Still, this often is the only way to obtain those data because of changing natural conditions (e.g. crossing paths in the Tatra mountains, which provide the only photo point available, are in quite different places after several dozen years). In addition to Digital Terrain Model, digital orthophotomaps were prepared by the author on the basis of images from 1955 and 1974, under own research scope. Those orthophotomaps will provide an information layer in the *Atlas of the Tatra Mountains* under preparation, edited by Dr. Władysław Borowiec.

Results of studies confirm the suitability of prepared materials, which proves the legitimacy of the adopted technology.

The analysis of aerotriangulation accuracy was conducted on the basis of probable average errors of photo point coordinates (RMS Control) and average probably errors of control points (RMS Check).

For example, the following results were obtained in relation to the set of TPN photos from 1974 (Tab. 2).

Table 2. Aerotriangulation accuracy in relation to the TPN photos from 1974

Parameter	*X* [m]	*Y* [m]	*Z* [m]	*XY* [m]
RMS Control	0.637	0.610	0.455	0.623
RMS Check	1.319	1.194	2.088	1.258

It has to be remembered that part of photo points was taken from the topographic map. The aerotriangulation was performed with the use of ISAT (Intergraph) software, owned by the Department of Photogrammetry and Remote Sensing Informatics, AGH University of Science and Technology in Krakow.

Radiometric improvement of images

Another crucial issue that relates to the utilisation of archival materials is that of their radiometric quality. Various methods of image filtration, as well as application of "manual" digital retouching under graphic programmes of the Adobe Photoshop type were tested. Archival photos are marked mainly by their poor contrast and high level of noise, resulting from the way they are stored.

In order to enhance the image contrast, filters that sharpen digital image edges, such as USM, as well as other high-pass filters were used which, once the input image has been filtered, were added to it. Mainly Gauss filtration was used to automatically remove noise from the image.

Fig. 1. Image obtained as a result of the original photo scanning (a). Image after filtering and edge sharpening (b)

Examples of image quality improvement are presented in figure 1. On the left, there is an image after it has been scanned, with visible grain coarseness, while on the right the same image with "sharpened edges" and subjected to smoothing filtration.

Images so prepared are then subjected to overall tonal balancing, with the use of advanced software, such as OrthoVista (by INPHO).

2.4. Supplementing the Existing Materials with Additional Data (e.g. Ground Photos)

Archival photogrammetric materials in the form of aerial photos can be supplemented with other data. The author contemplates to develop, under subsequent own research projects, the technology of "combining" aerial photos with ground ones, which means that objects (e.g. buildings) originating from vectorisation of 3D aerial photos will be provided with texture, obtained from archival ground photos dating back to the same period of time. That subject is presently developed under other projects. Research work will make use of aerial images of Krakow acquired under the project, as well as ground photos of the Main Market Square in Krakow that were made in the same time period (the 1960s). The results will be published on the Internet.

2.5. Feeding the Databases

It has been mentioned before that documents in the form of orthophotomaps, digital terrain models, or other 3D objects can serve as elements to feed databases. In the case of half-tone screen documents, data can be stored in two formats, that is *.tif and *.jpg. When stored in the *.tif format, they can provide access to the original data at any time, whereas those stored in the *.jpg format can be easily made available, e.g. on the Internet, due to the small file size.

Documents prepared under this research project, i.e. photographic mosaics, digital terrain models, and orthophotomaps for two selected areas, that is the Słowiński National Park and the Tatra National Park, will feed the GIS databases of those parks.

In addition, orthophotomaps prepared for the TPN will serve as information layers for the *Atlas of the Tatra Mountains*. Those layers have already been submitted to the TPN and already first analyses have been made on them (e.g. the change in the mountain pine lines during last 50 years).

The photogrammetric data related to Krakow will be made available on the Web page of the Department of Photogrammetry and Remote Sensing Informatics, in combination with information from other archival sources (archival maps acquired from the state archive in Krakow), as well as ground photos.

3. Exemplary Projects

The technology proposed herein was implemented in several research projects. It was used when preparing data for the Słowiński National Park under the

research project No. N304 077 31/3060, financed by the State Committee for Scientific Research, and titled *Spatial Modelling of Changes in Selected Elements of the Słowiński National Park* and for the Tatra National Park, where *Atlas of the Tatra Mountains* is prepared in cooperation with the Park management authorities, and the author hereof is also a co-author of the *Atlas*.

Whereas investigation of nature focuses on changes in natural environment, such as migration of seaside dunes (SPN), or changes in high-mountain vegetation (TPN), in the case of urbanised areas we expect, in addition to environmental changes, information on changes in infrastructure. Hence an attempt to apply the said technology to investigate urbanised areas.

Archival materials related to the area of Krakow were obtained under the project. They will be utilised to construct a multi-temporal database of the Department of Photogrammetry and Remote Sensing Informatics. Images were obtained from the Central Office of Geodesic and Cartographic Documentation (CODGiK) in Warsaw for the following year sets (Tab. 3).

Table 3. Specification of archival materials from the area of Krakow (1968–1993)

Scale	Year
1:2500	1968
1:2500	1969
1:4000	1970
1:18000	1970
1:17000	1975
1:16000	1982
1:30000	1993

The main obstacle, which recurred in the course of material searching and collecting, was the lack of fly mission plans, which limited search works and made them highly time-consuming. The problem can be eliminated through collecting such data and arranging them in specially prepared databases that the CODGiK does not have yet.

Another limitation to the full utilisation of information from archival air images is the issue of camouflage. This concerns mainly the urbanised areas, in which there were various military structures and facilities. The photographic mosaic of air images made in Krakow and its area in 1970 and in 1982 (Figs 2, 3) shows clearly the problem.

Following the requirements of the martial law in Poland, the images were highly distorted by means of additional information, or actually, by removing it. White spots indicate the necessity of supplementing the orthophotomap with other image texture, so that not to leave the map in that way.

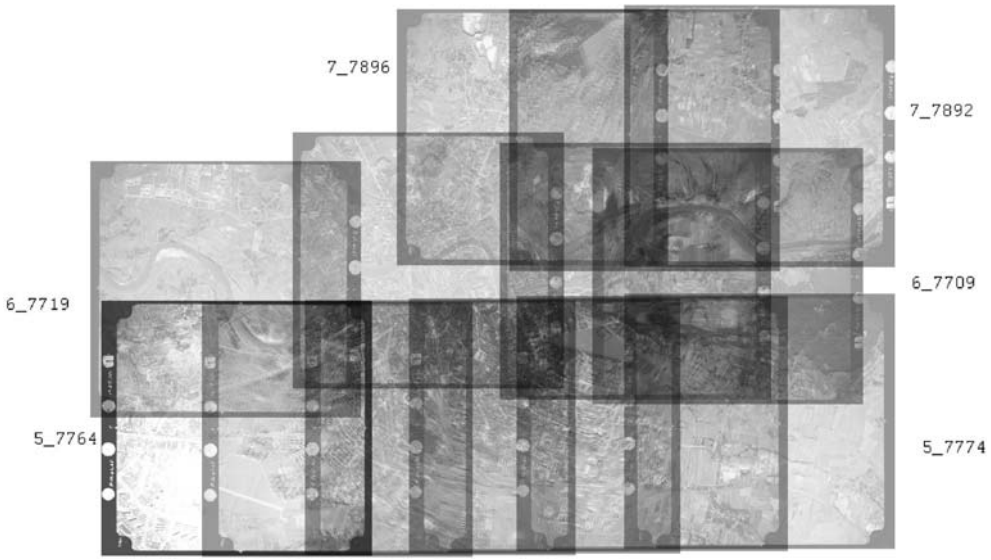

Fig. 2. Photographic mosaic of aerial photos from the area of Krakow (1970)

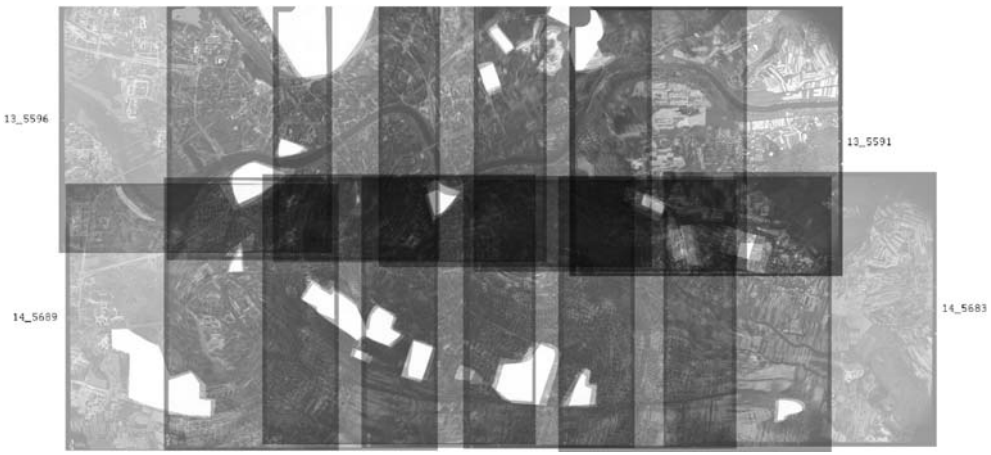

Fig. 3. Photographic mosaic of aerial photos from the area of Krakow (1982)

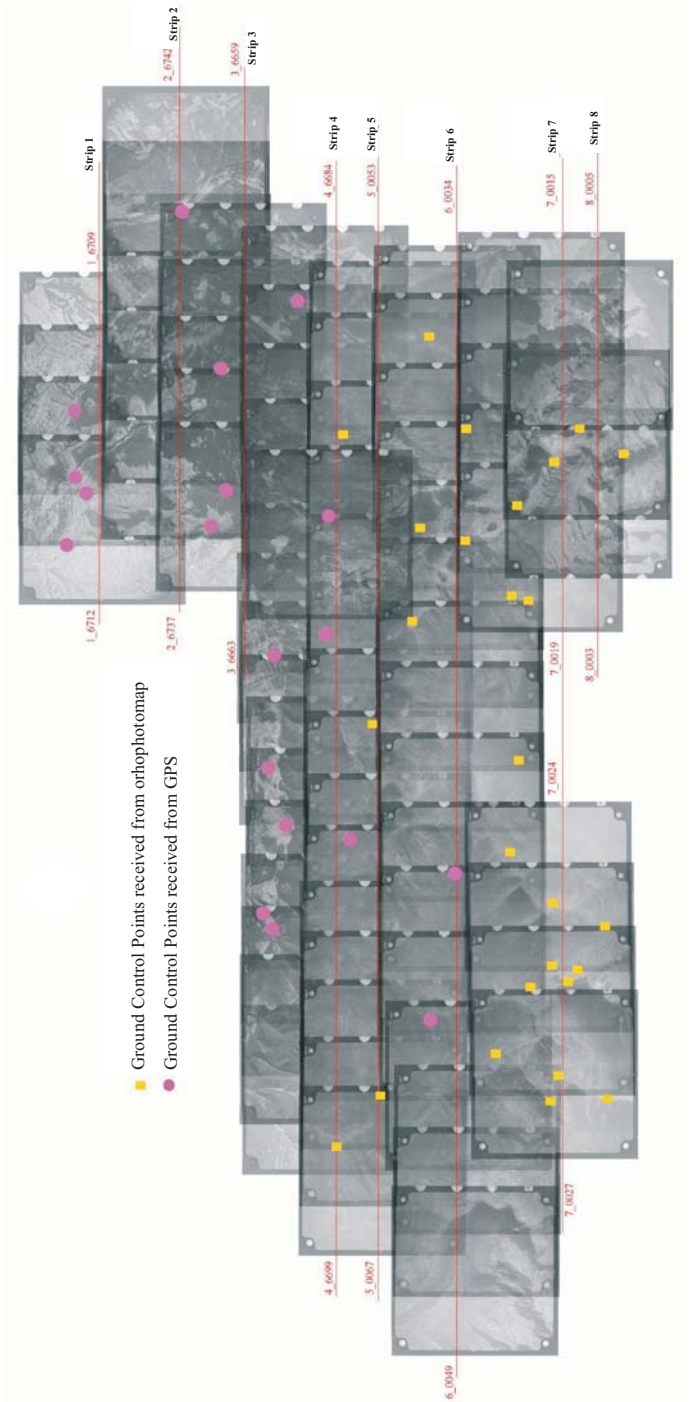

Fig. 4. Photographic mosaic of 1974 images, with approximated location of control points

4. Conclusions

The methodology of preparing photogrammetric documents on the basis of archival materials (post-war aerial photos), which is presented in this paper, is based on the proposed technology. It was tested at several projects, in which time span and quality range of materials were quite considerable. The time span covers the period of ca. 40 years (the oldest photos date back to 1955). The archival materials were marked up with high diversity, both as regards their geometry (photo negatives, duplicates), and radiometry (different photo scales, different seasons of the year, changing lighting conditions). The analytic determination of missing data parameters, as well as methods of enhancement of the radiometric image quality constituted main innovative plots of the proposed technology. All that was prepared with the use of that technology can be of considerable, practical significance, and can be used in various ways, as mentioned in the introduction. The archival materials in the form of aerial images, as well as their derivatives (DTM, orthophotomap, photographic mosaic) can successfully feed GIS databases and provide valuable material, especially for multi-temporal analyses.

References

[1] Baldi P., Fabris M., Marsella A., Monticelli R.: *Monitoring the morphological evolution of the Sciara del Fuoco during the 2002–2003 Stromboli eruption using multi-temporal photogrammetry*. ISPRS J. Photogramm. Remote Sensing, 59 (4), 2005, pp. 199–211.

[2] Bologna R., Minchilli M., Scognamiglio A.: *Risk Assessment For Environmental Applications: Integrated Analysis of Spatial Data Using Multi-Temporal Digital Orthophotos and Remote-Sensing Satellite Images.* XXth ISPRS Congress, com. IV, Istanbul 2004.

[3] Chander J., Cooper M.: *Monitoring the development of landslides using archival photography and analytical photogrammetry*. Land Miner. Surveying (Royal Institution of Chartered Surveyors), 6, 1988, pp. 576–584.

[4] Chander J., Cooper M.: *The extraction of positional data from historical photographs and their application in geomorphology*. Photogramm. Rec., 13 (73), 1988, pp. 69–78.

[5] Eyers R., Mills J.: *Subsidence Detection Using Integrated Multi Temporal Airborne Imagery*. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 34, Part XXX, 2004.

[6] Falkowski P., Kurczyński Z., Uchański J.: *Ortofoto zniszczonej Warszawy*. Geodeta, luty 2007.

[7] Kim M., Ednie A., Daigle J.: *Detecting Vegetation Change Using Multi-Temporal Aerial Photographs at Cadillac Mountain in Acadia National Park, Maine*. Proceedings of the Northeastern Recreation Research Symposium, 2006.

[8] Ricchetti E., Ricchetti G., Sani R.: *Environmental-Geological Study of Coastal Areas of Salento Peninsula (Southern Italy) using Multitemporal Aerial Photography and Satellite Imagery*. IEEE International Geoscience and Remote Sensing Symposium Proceedings, Alaska 2004.

[9] Zanutta A., Baldi P., Bitelli G., Cardinali M., Carrara A.: *Qualitative and quantitative photogrammetric techniques for multi-temporal landslide analysis*. Annals of Geophysics, Vol. 49, No. 4/5, 2006.