THE NATIONAL ORTHOPHOTO PROGRAM OF HUNGARY COMPLETED UNDER STRICT QUALITY CONTROL

Peter Winkler,
Institute of Geodesy, Cartography and Remote Sensing (FÖMI).
H-1592. Budapest. Po. box 585 - Hungary
peter.winkler@rsc.fomi.hu
www.fomi.hu
WG IV/5

Keywords: Photogammetry, GIS, aerial triangulation, data mining, orthoimages, digital elevation model, meta database, quality checking,

ABSTRACT:
Within the frame of the European Harmonization Program of the Ministry of Agriculture and Rural Development, three nation-wide connected projects were launched by FÖMI in 2000 to be carried out during 3 years. These are the following: a.)"Wall to wall Aerial Photography of Hungary"; b.) Creation of a 5m x 5m/1 m Resolution DEM of Hungary; c.) Set-up of Full Digital Orthophoto Coverage of Hungary. The project "Aerial Photography of Hungary 2000" was finished successfully during a relatively short period of time (3 month). Now, about 7000 aerial photos at scale 1:30 000 in analogue and digital forms are available in the archives of FÖMI.

As a result of the projects completed in the past 30 years till 1999, Hungary is covered now by ~ 4100 topographic map sheets at scale 1:10 000 in analogue form. The estimated and overall quality-controlled accuracy of contour lines is ± 0.5 - ± 1.5 m, in line with the national standard. This served as a basis for creating a high-resolution DEM of Hungary. The vectorization of the contour lines for the whole country was finished in May 2003. A complete photogrammetric technology was elaborated: analytical and digital aerial triangulation based on existing 4th order national triangulation network for determining the orientation elements of each aerial photo. The technology includes the creation of orthophotos on the base of DEM derived from topo-map contour lines and also the orientation elements of aerial photos adjusted for the whole country. During the creation of digital orthophotos a technology for overall quality control of the full process was applied. In line with this new quality control technology, we used the highly precise triangulation network of Hungary, (more than 50 000 points), ground-truth GPS measurements and other techniques. As a result of the quality control, the estimated accuracy of the DEM (consisting of about 4 billion raster points) is about ± 0.7 m in Z; the accuracy of digital orthophotos is about ± 0.6 m in X and Y co-ordinates.The quality-checked orthophotos of high resolution were archived as part of a metadata base and are available for the use by end-users of several professions and can serve as common spatial reference for the Hungarian GIS and RS systems.

Background

A modernization programme of the Hungarian Republic contains among others the aerial survey of Hungary as an independent duty, based on a Government Decree. Within the framework of the ANP (ANP = Acquis National Programme) EU harmonization programme (1,2) later on supported by the Department of Lands and Mapping of the Ministry of Agriculture and Rural Development (DLM MARD), three large, interconnected programmes were launched (under common name: Digital Orthophoto Programme of Hungary – MADOP) in 2000 for:

- Aerial photography of Hungary at scale 1:30 000;
- Creating 5m x 5m grid size DEM (Digital Elevation Model) of ±1 m accuracy in Z;
- Using the data resulting from the above two activities, setting up a full digital orthophoto coverage of Hungary that corresponds to scale 1:10 000.

The primary aim of the aerial survey of the country performed everywhere in almost identical period of time and in uniform scale was to develop *a digital image database covering the whole territory of Hungary in the Uniform National Projection System (EOV)* that corresponds to the scale 1:10 000, of a resolution at least 1m. It was planned to reach this goal by digital photogrammetric processing of the aerial photographs taken with metric camera and using the existing map base. The resulting database – beyond its further use for cartographic purposes – can serve as a basis for setting up any optional GIS, providing compatibility/interoperability of and connecting similar systems developed for various purposes in various places, in the *interest of assuring an easily handling system for the geometric order of the country*. One can understand its importance in the national economy, considering its possible use at various levels (national, regional, local and further on continental) and in various sectors (environmental protection, agriculture, water management, civil security, regional development etc.).

Our intention was to produce aerial photographs, which can serve as a basis of satisfying multipurpose user demands:

1. Digital data for the Hungarian Topographic Programme.
2. Correction/revision of EOV topographic maps at scale 1:10 000, using digital orthophotos.
3. Digital orthophotos for the National Cadastre Programme, supporting the planning of the digital revision of maps of rural areas at scale of 1:4 000.
4. Parcel-level digital photomaps for supporting the performance of duties connected to the IACS (Integrated Administration and Control System for future EU agrarian subsidy).
5. Providing up-to-date data for regional planning in areas damaged by floods or the waterlog.
6. Additional information for developing the CORINE 1:50 000 land cover database.
7. Performing interpretation jobs of various purposes in other fields of activity.
8. Any others.....

1. „Aerial Survey of Hungary, 2000" (3)

To ease the selection of such a scale for the aerial survey, which covers the whole country and can be produced and handled easily, also allows multipurpose use, we prepared the flight plans for aerial survey at various scales. The calculations were performed so that Hungary was placed into an imaginary rectangle. On this basis, a comparative analytic table (*Table 1*) was made to help the decision-making concerning this countrywide aerial survey campaign.

Table 1 Aerial mission planning data for decision-making

Scale of the aerial survey	Number of photographs (pcs)	Duration of the aerial survey (incl. turns) in hours	Ground resolution of the aerial photographs (in cm)	Scanning 21μm: one picture is 375 MB
1:10 000	58 812	192	8 - 12	22,1 TB
1:20 000	14 732	96	20 - 25	5,5 TB
1:25 000	9338	77	25 - 32	3,5 TB
1:30 000	**6591**	**65**	**30 - 36**	**2,5 TB**

Note to Table 1: We performed similar analytic calculations for various aperture before selecting the 21 μm aperture for scanning, too.

After examining the economic efficiency of the aerial photography and the photogrammetric processing, we decided to use 1:30 000 scale for aerial survey. When using this scale – confirmed by the data in the Table 1 – we can achieve almost identical goals of usage, also compared to scale 1:25 000, if we process an amount of images less by 50%.

In the year of Millennium 2000 the winning company of the public procurement procedure, EUROSENSE Ltd. successfully performed the aerial survey of the whole area of Hungary within about three months and in conformity with the very strict „Technical specification", elaborated by FÖMI. (4).

The number of photographs aquisited within the programme „Aerial Survey of Hungary 2000" and handed over to FÖMI for archiving and data supply services is listed in Table 2.

Table 2 Number of photographs archived by FÖMI

	Number of repetitions				All projection centre	Digital images pcs	Colour slides pcs
	1^x	2^x	3^x	4^x			
Number of projection centres	5884	719	32	7	**6642**		
Including repetitions	5884	1438	96	28			7446
Handed over to FÖMI						**6667**	**7446**

2. Producing Digital Orthophotos

The technology of producing digital orthophotos can be shown in three main steps (5), (see figure):

Step I. Determining the absolute orientation elements of the images by aerial triangulation using bundle adjustment.

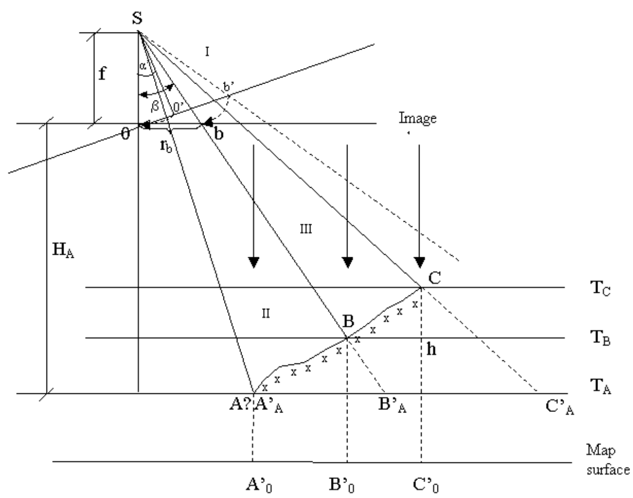
Step II. Producing the digital elevation model (DEM).

Step III. Production of digital orthophoto by simultaneous use of data determined in Steps 1. and 2. and transforming the image elements pixel by pixel.

Beyond the use of high-tech technologic instruments and keeping strict technological discipline, significant amount of work time and costs are necessary to perform all these. Therefore, when carrying out this countrywide job, a uniform technology should be applied, which

- Provides the maximum accuracy, which can economically be achieved from the given aerial photographs;
- Considers the opportunities offered both by traditional and up-to-date photogrammetric procedures;
- Is optimal in duration, beyond its cost-efficient, economical technical solution;
- Is built on the national databases developed by FÖMI during several decades and representing significant value;
- Provides the uniform quality and accuracy of the digital orthophotos, wherever they were produced;
- Provides the state acceptance of the orthophotos with a certificate guaranteeing their quality;
- Supports the development of metadatabase needed for further marketing and archiving;
- Serves as a basis for the revision of the EOV topographic maps at scale 1:10 000 and the start of the Hungarian Topographic Programme.

Figure 1: Main steps of producing orthophotos



2.1. Aerial Triangulation

The development of the fourth order geodetic triangulation network of Hungary started in mid seventies and was finished by 1992. In accordance with the specifications, the density of the fourth order points is 1 point/2 km^2 in rural areas, while denser in the built-up areas, i.e. less than 1 point/1 km^2. The accuracy of the fourth order network is very good: ± 3-4 cm. The network is built on the points of the higher order triangulation network, so it forms *a countrywide uniform geometric basis*.

When realizing MADOP, it was advisable to match the blocks of aerotriangulations to those points. The accuracy of the fourth order points is much better than the accuracy values, which can be achieved from aerial images at scale 1:30 000, so they serve as a reliable basis for geometric matching of the aerial triangulation blocks. As a result of the aerotriangulation block adjustment, we have got the orientation parameters of the individual aerial photographs (see the figure, step I), which enable us to fit the aerial photographs into the national geodetic control network within the error limit of the aerial triangulation. The accuracy of the orientation parameters of the aerial photographs and the reliability of the DEM together will determine the accuracy of the digital orthoimages to be produced, i.e. the accuracy of the matching into the national geodetic control network.

The fourth order points stabilized in the field by concrete panels are hardly identifiable on the aerial photographs without preliminary marking in the field. But using a specific aerialtriangulation measuring procedure, considering the given technical conditions, we managed to reach that the digital orthophotos match each other in a countrywide uniform geometric order, thanks to having used the fourth order points as control points identified and measured in corresponding quantity.
From 2001 to 2003, we have performed the aerotriangulation more (due to the overlapping aerial triangulation blocks), than of 6 667 aerial photographs covering the territory of the whole country, at the beginning by using original colour slides and analytic method (CartoHansa), later on by digital procedure based on raster aerial photos (Eurosense).

Table 3. Summarized statistics of the aerial triangulation results

Aerial triangulation procedure	Quantity of photographs (pcs)	Quantity of tie points (pcs)	Quantity of control points (pcs)
Analytical	4163	65122	11963
Digital	3103	94585	13502
Altogether	**7266**	**159707**	**25465**
Quantity of unknowns	*43596*	*479121*	

Depending on the current job, the size of the aerotriangulation blocks was changing between 50 and 500 aerial photographs. Tables Nr. 3 and Nr. 4 show the statistical analysis.. From Table 4, one can state that the accuracy of the countrywide geometric fitting of the original aerial photographs can be described by ± 0.20–0.25 m X,Y co-ordinate mean error that is a very good value.

Table 4. Summarised accuracy of the aerotriangulation performed in blocks

Aerotriangulation procedure	Field accuracy			Accuracy projected onto the image plane		
	m_x (m)	m_y (m)	m_z* (m)	m_x (μm)	m_y (μm)	m_z* (μm)
Analytic	± 0.23	± 0.26	± 0.44	± 7.5	± 8.5	± 14.6
Digital	± 0.16	± 0.16	± 0.10	± 5.5	± 5.3	± 3.0

* The result of m_z of digital aerialtriangulation is only a theoretical (mathematical) value and not a real one. The real value of determination of Z co-ordinate is the result of analytical triangulation, e.g. ± 0.44 m.

2.2. Producing the Digital Elevation Model (DEM)

The digital elevation model (DEM) needed for producing orthophotos can be developed by various methods:

1. In analytical instruments, by semi-automatic grid-measurement,
2. By automatic processing, based on digital stereopairs, using suitable hardware and software.
3. By vectorizing contours and other relief elements of the existing topographic maps.
4. By other methods (e. g. aerial survey using laser, detailed GPS survey etc).

As it is known, FÖMI Archives keep not only the colour prints of the 1:10 000 topographic maps, but also the overlays of the relief, planimetry, hydrography and the geographical place names on original stable transparencies. A decision was made for MADOP that the contours presented on the *relief (contour lines) overlay* of the 1:10 000 topographic maps will be vectorized to create the EL_DEM_5 grid model with reduced content, which is accurate enough for producing the orthophoto (see figure Step II.). The reduced content refers to the fact that the relief element of the topographic maps /hollow, dike etc./ presented on their *planimetric and hydrographic overlays* can only be presented after vectorizing the relevant overlays. Namely, the available funds did not allow to make all three overlays vectorized at the same time.
A decision was made for applying this procedure because of the reasons listed below:
Several studies and projects deal with the *automatic digital photogrammetric procedures*, mostly stressing their advantages, but forgetting about that practically no data can be produced from aerial photographs the content of which is 100% ground true. Without going into details when analysing this theme, it is worth paying attention that after *finishing any photogrammetric procedure, a subsequent field check has always been necessary* for completing the data that cannot be seen in the photograph, wrongly displayed or proved to be non-interpretable.
This was the case too, when producing the topographic maps of Hungary at scale 1:10 000. During the 25 years (1975 – 1999) of the topographic programme, the applied technology has changed a lot. However, it can be stated that the majority of the map sheets was produced on the basis of aerial photographs, in various photogrammetric procedures, but also using a significant amount of additional field measurement data, following the strict technological specification and accuracy requirements prescribed in the Hungarian Standard for Topographic Mapping - T.1. (6)
In 2000, to be convinced of the accuracy of the relief presentation on the existing 1:10 000 topographic maps kept in FÖMI Archives, FÖMI invited the Department of Photogrammetry and GIS (Economic and Technical University of Budapest) and also the Department of Photogrammetry (College of Geoinformatics, University of Western Hungary) for the assessment of the relief of the above mentioned maps. Both institutions, independently from each other and using different measuring methods have examined 40-40 different mapsheets at scale 1:10 000, selected at random. They both prepared their studies discussing the results of the assessment. (7, 8). The authors of those studies have measured altogether 7500 checkpoints being in various areas. They placed the points measured in 2000 into a co-ordinate system of topographic maps produced 10-15 years earlier. The elevation co-ordinates of the measured points were compared against the elevation data interpolated from contours of the maps, and they calculated the differences.
Independently from each other, both came to the following conclusions:

1. The changes of relief since the production of the maps – expressed in percentages – are not considerable.
2. Where significant changes occurred, the differences in altitude appeared as blunders.
3. According to the checking procedures, apart from the extreme cases like in the former point 2, the average error of relief presentation remained within the error limit specified in Technical Instruction T.1.

Table 5 shows the results of the assessment performed in 2000.

Jobs completed for producing Digital Elevation Model:
a) Creating digital raster database (DRTA_10) of the topographic maps at scale 1:10 000 and of EOV projection.
Within the EU ANP Harmonisation Programme of the Department of Lands and Mapping, Ministry of Agriculture and Rural Development (DLM MARD) and partly as an official job,

Table 5. Accuracy control of contour lines of the topographic maps at scale 1:10 000

Assessment performed by	1^1 m		2.5^1 m		5^1 m	
	pcs[2]	z (m)[3]	pcs[2]	z(m)[3]	pcs[2]	z(m)[3]
Department of Photogrammetry and GIS, Technical University, Budapest	815	±0,56	1826	±1,03	35	±1,0
College of Geoinformatics Univ. of Western Hungary	2316	±0,47	2313	±0,73	-	-
Accuracy norms of creation of contour lines by Technical Instruction T.1.		*± 0.40*		*±1.0*		*±2.0*

Remarks:
1 – value of contour interval on the map
2 – quantity of points involved in the examinations
3 – mean error of „Z" differences given in meters

FÖMI performed the scanning and geo-coding in EOV System of the colour prints, planimetric, hydrographic and contour lines overlays of the 4098 topographic maps at scale 1:10 000, which cover the whole territory of Hungary. The datasets in raster form have continuously been serviced by FÖMI since the beginning of 2001. Within the framework of this programme, our intention was to produce a raster dataset of topographic maps for various purposes. In this way, for example during the aerialtriangulation procedure, the control points – which are needed for preliminary orientation of the aerial images – can be selected using the planimetric overlays. By projecting the transparent planimetric, hydrographic or relief overlays onto the ready orthophotos, the readability of their content can be increased. They can serve as a basis for planning revision programmes etc.

b) Digital Elevation Model of Hungary (EL_DDM_5, J_DDM-5) with a grid density of 5m x 5m, produced by vectorizing the contour lines
Technological description was prepared for vectorizing the contour lines overlays of the 1:10 000 topographic maps. It is the basis of creating the so called „preliminary" digital elevation model called EL_DDM_5 with reduced content, grid density of 5m x 5m and elevation accuracy of 1m, aiming at providing uniform quality and results (9, 10). This DEM is needed for creation of the digital orthophoto. In 2000, within a public procurement procedure, we managed to make the vectorization of relief overlays of 1400 map sheets completed (Alba Geotrade Co., Geoadat-GAF). By December 2001, FÖMI finished the vectorization of relief of further map sheets as part of governmental and other external jobs (with PGT Co. and Carto-Hansa Ltd.). In 2002, there came a new opportunity again in the form of open public procurement procedure to make relief vectorization of further 860 sheets finished (Flexiton Ltd.).
FÖMI experts or external firms (PGT Co.), following the FÖMI specifications have continuously supervised the results of the vectorization, corrected them or sent them back for correction, providing uniform quality of the digital transformation. FÖMI prepared specific software for checking the reliability of the vectorized contours. (11).
In 2002. a Government Decree by providing the development of the EU compatible GIS database for the Agricultural Land Parcel Identification System (LPIS; the Hungarian abbreviation - MePAR) speeded up the completion of the MADOP Programme. As a result of it, in October 2002, a public procurement procedure was announced for the remaining jobs in the territory of Hungary:

- Aerotriangulation of 2500 aerial photographs;
- Relief vectorization on 963 map sheets;
- Production of digital orthophotos for 3100 map sheets.

The winner of the tender, EUROSENSE Ltd. (with its two subcontractors: Carto-Hansa Ltd and DigiKart Ltd.) undertook according to the invitation to tender (14) to correct the *EL_DDM of 3100 map sheets by using the stereopairs* and complete it with the missing relief elements (hollows, dykes etc.), in other words, also produce the so-called corrected DEM, named J_DDM_5.
As a result of this programme, the aerotriangulation, the vectorization of relief overlays and the production of the 5m x 5m DEM was finished for the whole territory of Hungary by May 2003. Within that, the corrected and completed J_DDM-5 for 3100 map sheets got ready too.
Depending on availability of funds, we are planning to produce a final version of DDM_5, which will be suitable for engineering/planning jobs and also contains elevation elements that are shown on the planimetric and hydrographic overlays, but not by contours. To do so, we can use J_DDM, which is ready for 3100 map sheets, and also the „difference-DDM", which shows the changes. Accordingly, the corrected DEM still for about 1000 map sheets is to be produced (will be finished in middle 2004).
Based on the experience collected when checking the previously developed 100m x 100m DEM, FÖMI has elaborated a procedure for controlling the accuracy of the DEM, using the -co-ordinates of fourth order triangulation network, which consists of about 55 000 points.
The recently elaborated controlling program shows a very good level of reliability according to recent examinations performed with DEM-5 (Table 6); the results justify that our predecessors strictly followed the Technical Instruction T.1. during the 25-year long topographic programme and did a very careful, high level job. At the same time, the results of the examination also confirm that the participants of MADOP Programme – under the guidance and with efficient co-operation of FÖMI experts – in the past three years of hard workload did a great job too, when creating the computerized, digital dataset.

Table 6: Comparing the Z co-ordinates of points of fourth order network and the elevation of DDM_5

	Distribution of basic contour intervals			Total
Contour interval	1 m	2,5 m	5 m	
All points (pcs)	25118	25372	2653	53143
Rejected, difference >2.5 m* (pcs)	617	672	229	1518
Accepted points (pcs)	24501	24700	2424	51625
RMS (m)	*0,58*	*0,71*	*0.99*	*0,67*

Remarks:* error analysis of the points showing difference bigger than 2.5 m in progress

2.3. Producing the digital orthophotos

As a result of aerial triangulation we have the elements of absolute orientation of the aerial photographs with high accuracy. Based on these elements and the high resolution DEM also defined in EOV, we have transformed the original, perspective aerial photographs into orthogonally projected images, which correspond to the map system (see figure Step

III.). The resulting digital orthophoto has got the same content as the original aerial photographs, but it is free from those geometric distortions caused by the tilt angle of the aircraft and the relief effects. In the interests of the uniform job performance and supervision, FÖMI has worked out a Technical Documentation (14) concerning the procedure of producing digital orthophotos and performing related activities, the necessary technologic steps and geometric/photographic criteria. To achieve a better photographic quality, the orthophotos had to be produced in „re-sampling" 0.5m pixel size. If a certain map sheet was covered by images taken in different periods of time – aiming at assuring the corresponding quality of interpretation –, we did not allow performing colour adjustment within the said map sheet. In that case, also the date of the aerial survey had to be marked along the „cut-lines".

Considering the standpoints of archiving, service and unambiguous management, a procedure was elaborated also for quality control of orthophotos to be delivered in the form of map sheets, which corresponds to the scale 1:10 000. As a result of it, to every map sheet belongs a Quality Certificate, which guarantees the geometric and photographic quality of the digital orthophoto-sheets. Mostly FÖMI experts and an external company (Geodézia Co.) performed the quality check based on the viewpoints and specifications given by FÖMI. Evidently, orthophotos could be produced after performing the previous phases of work (aerotriangulation, creating DEM) on a given area. The performance was scheduled partly according to the needs, partly depending on the available financial resources. Accordingly, till November 2002, digital orthophotos were ready for an area covered by altogether 500 map sheets. Due to the acceleration effect of the Agricultural Parcel Identification System (MePAR), digital orthophotos were produced for 3500 map sheets between November 2002 and June 2003. (3100 by Eurosense Ltd. and its subcontractors, 400 by orthophoto quality supervising team of FÖMI, as if preparing themselves for the future quality acceptance procedure.) The quality check itself and the correction of the identified errors is being close to finish.

Corresponding the EU norms and using image-field identical points – in a random distribution all over the territory of Hungary for 259 map sheets – we made the X,Y co-ordinates of the orthophotos checked, in average 15-25 points/map sheet with GPS measurements (GeoLevel Ltd.). The results of this supervision summarized by the phases of performance (Table 7) verify that we managed to create a geometrically correct, highly accurate digital ortophotophoto database for the whole territory of Hungary , and which represents the status of the country in the year of the Millennium.

Table 7 *Summary of the results of the quality checking by GPS measurements*

Phase	Sheets (pcs)	Check points (pcs)	Rejected points (pcs)	Accepted points (pcs)	m_x (m)	m_y (m)
I.	99	1740	31	1709	± 0.65	± 0.60
II.	100	1737	21	1716	± 0.65	± 0.70
III.	60	1131	7	1124	± 0.58	± 0.55

Note: analysis of the rejected points is in progress

Summary

As joint achievements of the EU ANP Harmonization Programme of the Ministry of Agricul-ture and Rural Development and that of the MePAR (Agricultural Parcel Identification System), the following items were completed between 2000 and June 2003, and in the sequence of their completion they have continuously been serviced:

1. „Aerial survey of Hungary 2000" (at scale 1:30 000, from a height of 4500 meters, resulting altogether 7746 pieces colour slides, 6667 pieces of photographs digitized by scanning);
2. Aerotriangulation more than 6667 photographs;
3. Geocoded raster dataset of 4x4098 pieces of topographic map sheets/overlays at scale 1:10 000;
4. Vectorized relief of 4098 pcs map sheets and based on them a DEM of grid-density 5mx5m, comprising about 4 billion points;
5. 4098 digital orthophoto sheets of a volume about 2.5 TB.

As it was documented, all work phases were followed by strict quality control procedures. As a result of it, the digital orthophotos can be characterized by a co-ordinate error of ± 0.60 m and ± 0.70 m.
This level of accuracy is also valid to the measurable image elements of the map-like ortho-photos, which keep the whole content of the aerial photographs covering the whole territory of Hungary and having been completed in the year of the Millennium. This simply readable digital orthophoto – offering multipurpose information to everybody – can serv as a uniform GIS basis for the various fields of activity and circles of users. The reliability of DDM_5 is ± 0.70 m in average for the whole territory of Hungary. The digital elevation model can also be used independently for producing maps servicing the flood protection, logwater protection, maps of accurate slope categorization, showing the disposure, etc. The servicing of the DDM_5 has just started.

Our intention is to repeat the aerial survey campaign of Hungary every three years. In the future, it will be quicker to produce digital orthophotos from the new photographs as the necessary DEM is already available.

REFERENCES

1. Apagyi, Géza: Európai integráció és a földügyi igazgatás (*The European integration and the Hungarian Land Management Sector*) (Geodézia és Kartográfia, June 2001)
2. Remetey F., Gábor dr.: Szakterületi felkészülés az EU csatlakozásra – a 2000. évi ANP intézményfejlesztési programok *(Preparations in the Hungarian land management sector for the EU accession, institution development programmes, ANP 2000)* (Geodézia és Kartográfia, 2000. április)
3. Winkler, Péter: „Magyarország légifényképezése 2000" *(Aerial Survey of Hungary, 2000)* (Geodézia és Kartográfia, July 2001).
4.Winkler, Péter: A „Magyarország légifényképezése 2000" program keretében készített légifelvételek egész ország területére egységes, kiegyenlített geometriai illesztése. FVM FTF ANP EU Harmonizációs Program keretében készített tanulmány (*Countrywide uniform, geometrically adjusted geocoding of aerial photographs produced in the programme „Aerial Survey of Hungary, 2000" – a study prepared in the ANP EU Harmonization Programme of the DLM MARD*) (2001, FÖMI Library)

5. Winkler, Péter: Ortofotótérkép készítés Drobüsev féle réstranszformátorral (*Producing Orthophotos with Drobyshev Ortophoto Device*) (1968, thesis)
6. Komplex utasítás az 1:10 000 méretarányú topográfiai térképek készítéséhez (*Complex technical instruction for the production of topographic maps at scale 1:10 000*)(ÁFTH, 1966)
7. Detrekői, Á.: - Barsi, Á. – Mélykúti, G. – Szabó, Gy.: 1:10 000 méretarányú EOTR topográfiai térképek domborzati tartalmának ellenőrzése. FVM FTF ANP EU Harmonizációs Program keretében készített összegző jelentés (*Controlling the relief content of the EOTR topographic maps at scale 1:10 000, final report, prepared in the ANP EU Harmonization of the DLM MARD)*) (2000, FÖMI Library).
8. Busics, Gy. – Engler, P.: 1:10 000 méretarányú, földmérési topográfiai térképek domborzati tartalmának vizsgálata (FVM FTF ANP EU Harmonizációs Program keretében készített zárójelentés, (*Checking the relief content of the EOTR topographic maps at scale 1:10 000, final report prepared in the ANP EU Harmonization Programme of the DLM MARD*) (2000, FÖMI Library)
9. Iván, Gy. – Maucha, G. – Petrik, O. – Solymosi, R.: Technológiai eljárás az 1:10 000 méretarányú topográfiai térképek domborzatmodelljének előállítására, készült a FVM FTF ANP EU Harmonizációs Program keretében (*A technology for the digital elevation model of the topographic maps at scale 1:10 000, prepared in the ANP EU Harmonization Programme of the DLM MARD)* (2000, FÖMI Library)
10. Iván, Gy. – Solymosi, R. – Winkler, P.: Műszaki leírás az 1:10 000 méretarányú földmérési alaptérképek csökkentett domborzati tartalmának vektorizálásához, készült a FVM FTF ANP EU Harmonizációs Program keretében (*Technical specification for vectorizing the reduced relief content of the geodetic base maps at scale of 1:10 000, prepared in the ANP EU Harmonization Programme of the DLM MARD)* (2000, FÖMI Library)
11. Iván, Gy. – Solymosi, R. – Winkler, P. Nagyfelbontású domborzatmodell minőségvizsgálata, minőségbiztosítási eljárás-rendszere, a FVM FTF ANP EU Harmonizációs Program keretében készített tanulmány (*Quality control and quality assurance system for a high-resolution digital elevation model – a study prepared in the ANP EU Harmonization Programme of the DLM MARD)* (2003, FÖMI Library)
12. Joó, István – Mihály, Szabolcs – Csornai, Gábor: A magyar geodézia és távérzékelés hozzájárulása az EU csatlakozási feladatok megoldásához (*Contribution by the Hungarian geodesy and remote sensing to perform the duties in connection the EU accession of Hungary*) (Hungarian Academy of Sciences, 2001
13. Csornai, G.: A FÖMI távérzékelési és térinformatikai feladatai az EU csatlakozás elősegítésére (*FÖMI Remote Sensing and GIS duties supporting the EU Accession of Hungary,* (GIS Open Conference 2003, Székesfehérvár, 10-12 March, 2003)
14. Iván, Gy. – Solymosi, R. – Tóth, K. – Winkler, P.: Műszaki leírás „Magyarország Digitális Ortofotó Programjának" (MADOP) befejezésére, készült a FVM FTF ANP EU Harmonizációs Program keretében (*Technical Specification for completing the MADOP Programme (Digital Orthophoto Programme of Hungary, prepared in the ANP EU Harmonization Programme of the DLM MARD)* (2002. FÖMI Library)