A Digital Landscape Model for Europa (DLME)
A European Challenge to Remote Sensing

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INTRODUCTION

Although remote sensing activities nowadays being performed are manifold, their integration into a superior scientific goal including further methodical developments has still not been realized.

This background stimulated the OEEPE (European Organization for Experimental Photogrammetric Research) to conceive and to launch a pilot study under the title "Digital Landscape Model for Europe".

The DLME seen under this aspect is based on the integration and focussing of the various efforts, options and objectives presently being pursued in the fields of remote sensing, photogrammetry and cartography. Thus, the DLME understands itself as

- a concept for the dynamic integration of different sensor recordings and evaluation results with the aim of subsequent operational usage and
- as a driving force in the development and application of refined analyzing and processing methods suited for dealing with highly topical problems.

The superordinate performance criteria of this concept consists in its capability of covering not only specific interests of the various sections within the photogrammetric, remote sensing and cartographic fields, but also desires of various external users (e.g. from the fields of agrarian statistics, environemntal protection, etc.) at different levels (E.C., state, region, municipality, etc.)

1. CONCEPT

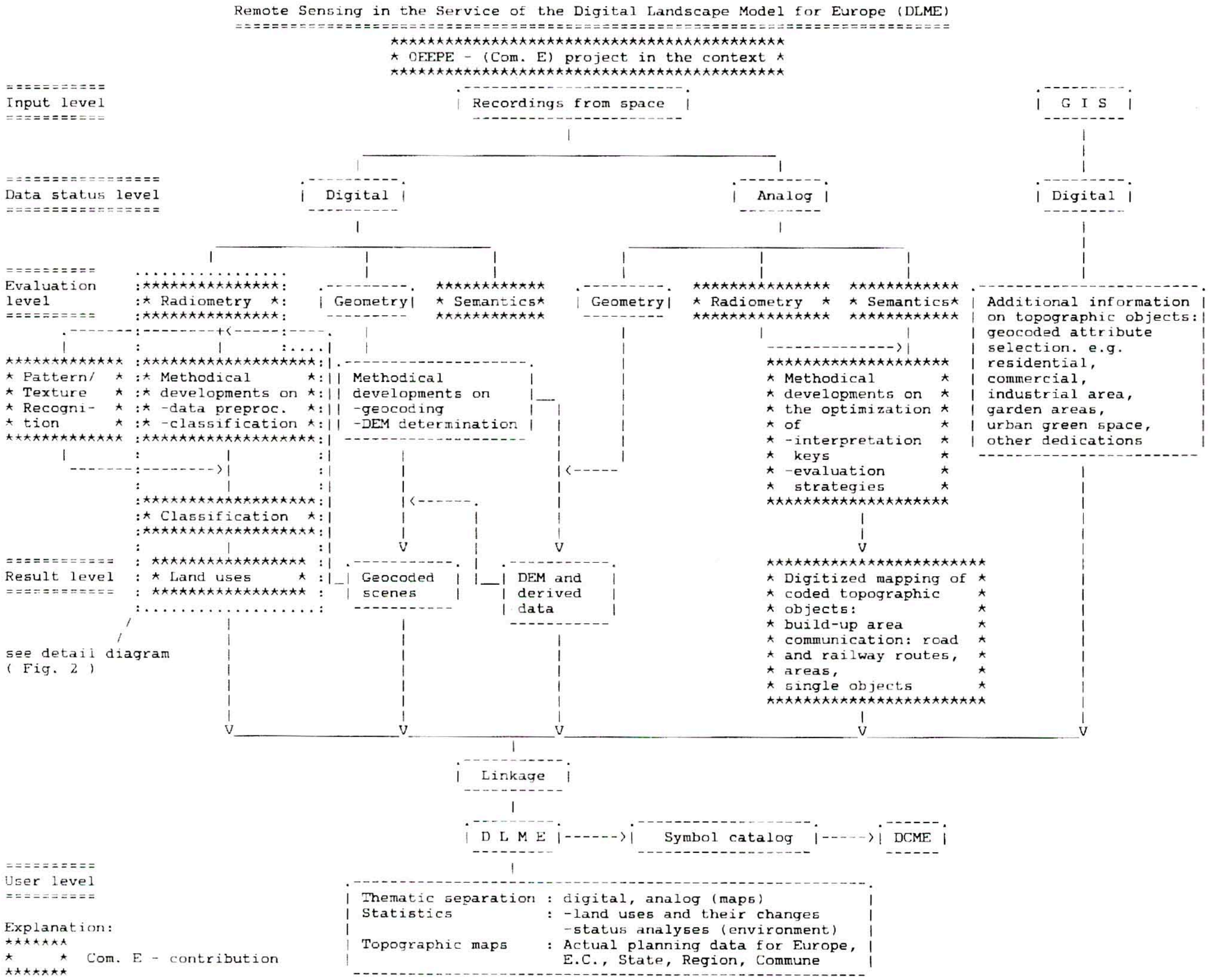
1.1 Data concept

The joint evaluation of digital and analog recordings from space constitutes an essential starting point with regard to realizing the DLME concept. In accordance with the common procedures of geodesy (from large to small) only relatively coarse thematic and topographic information could at first be derived from these recordings, due to the presently achievable geometric resolution of remote sensing systems (as compared to the object accuracy required in large-scale cartography). However, an information frame capable of being established in this way could be filled, extended or substituted stepwise there - and from here the problem calls for a dynamic approach - where densified information and increased accuracy can only be achieved by a dedicated (local) integration of higher resolving remotely sensed data.

Considering that one could make use of an operational MOMS-02- system, which - if put into operation together with GPS - could fulfill the accuracy requirements made on the landscape model (planimetric accuracy ± 3 m) by the state survey administrations, the presently still occuring defiencies as, e.g., insufficient resolution and accuracy, seem to be remediable within the foreseeable future.

In case that in addition to the space recordings pre-set by the concept, aerial imagery obtained at different flight altitudes and with different detail resolution would be admitted for application-oriented selective information densification, the total dynamically usable data space for the landscape model would thus be described.

The original concept of the OEEPE, however, was not so far- reaching. Furthermore, for financial reasons one investigation area covered by the topographic map L 5916 (Frankfurt a.M. EWest 1:50 000), and to be selected, though further alternatives would have been available. LANDSAT 5 TM recordings of 2 different dates as well as 2 area-covering KFA-1000 stereo models form the data basis. In the meantime, IGN has taken care of the financing and supply of the corresponding SPOT-P (panchromatic) stereo recordings. Through this contribution the data basis



itself and the pertaining possibilities of evaluation can be considerably extended.

1.2 Evaluation Concept

Starting from the topographic and cartographic basic data of a landscape model (transport system, land uses, waters, relief, single objects) which can be summarized into relief, punctiform, linear and areal objects while placing the emphasis on the geometric component, and from the remote sensing capabilities of describing the latter, the necessity arose to pursue information acquisition from different data sources:

- areal objects including their contents (land uses, waters) shall be determined through the classification of multispectral recordings
- linear objects including their contents (transport system) shall be determined in the course of the 3-dimensional photogrammetric evaluation of images, subsequent to the development of interpretation keys and evaluation strategies by means of coded vectorization. As an alternative, the concept provides for the development and use of the texture and pattern recognition
- the terrain relief shall be determined on the basis of digitized recordings (SPOT) and digitized analog recordings (KFA- 1000) as well as photogrammetrically from stereo image pairs
- acquisition of punctiform or single objects is dependent on the geometric resolution; hence, this is hardly achievable considering the data available.

An indispensable prerequisite for full exploitation of the information contents of multisensoral and - if available - multitemporal multispectral recordings by means of classification consists in

- their exact relative geometric referential quality (with sub- pixel accuracy), which cannot be achieved through conventional methods (e.g. power polynomials), as well as

- the application of the DEM and data derived therefrom for radiometric and geometric correction of the measured values (geocoding).

Finally, linkage of the geometric and thematic information thus obtained with functionally descriptive object attributes (see Fig. 1), which are filed in a specific GIS, leads to a landscape model derived exclusively from space recordings.

2. METHODICAL DEVELOPMENTS AND FIRST WORKING RESULTS OBTAINED BY IfAG

The requirements of the in practice to secure short-term and area-covering land use information of planning relevance in pixel accuracy concerning location and contents, or even to supply, e.g. various damage degrees of vegetation, cannot be fulfilled prior to substantial evolution of methods of obtaining, processing and linking radiometric, geometric and semantic data and information, respectively, from digital and analog recordings, the inclusion of digital additional information (object attributes) is a further prerequisite with regard to meeting the aforementioned demands. The development and provision of such methods therefore constitutes the kernel of the project.

Considering thet the project has been launched only a short while ago and that the organizations involved have therefore not yet presented any methodical developments, or even complete results, only IfAG activities concerning the field in question can be reported about.

It is already long since IfAG started to work continuously on partial aspects of the overall project and to treat particular problems from the fields of classification and digital correlation. Except for the development of methods suited for texture and pattern recognition, the entire working of digital recording evaluation can thus be met.

Investigations of the geometry of KFA-1000 image as well as on the interpretability of linear topographic objects were perfomed in the course of the project. Beyond that, there have not yet been gained any experience on

- methodical developments for the optimization of interpretation keys and evaluation strategies. (One should probably not start from the assumption that the object type catalogue applied to the Official Topographic Cartographic Information System (ATKIS) of the Working Committee of the Survey Administrations of the Federal Republic of Germany (AdV) will be accepted also the international project level),
- the setting-up of a GIS which contains functionally descriptive feature attributes and makes possible the assignment of land use and function, as well as
- on the linkage of remotely sensed basic data relevant to the landscape model.

Investigation of the latter range of themes is the responsability of dedicated working groups outside IfAG.

2.1 Digital Recording

2.1.1 Evaluation of Radiometric Measurements

An essential task of remote sensing is the acquisition and separation of land uses (see above: aeral features) through the classification of multitemporal and multisensoral multispectral recordings, or of their transforms and the features derived therefrom (texture, form,...).

As long as no effective procedures are available to transform multitemporal and multisensoral multispectral recordings onto each other (see 2.1.2) with a high degree of geometric accuracy (below the edge length of a pixel) and to evaluate them simultaneously, or to determine the aforementioned additional features, one must necessarily have recourse to the classification of single multispectral recordings. However, the hit rates published on these processes, to be read from the confusion matrices, amount solely to 50 % to 80 % and therefore to be considered as insufficient for high level present-day applicational purposes. For this reason IfAG has during the recent past done much research on the causes of unsatisfactory separation capability and laid down the respective results in refined analytical and evaluative methods. [Schulz, 1988 - 1990]. These methods can now be entered into the project and undergo further refinements in accordance with the objective of automatization (see Fig. 2). In the following are given some key terms comprising the most essential assertions.

Normalization

Normalization aims at improving the comparability of multiple recordings of one sensor type over the same area of recording (sensor drift) and of simple recordings over adjoining areas (extrapolation). The method is based on the transformation of all spectral channels onto the same variance and the same mean value.

Data compression

Due to the fact that single channels are often higly correlated, in general their principal components are computed. However, as regards further processing, only as many and

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                         Detail diagram                   Figure 2
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           | Multi        |
           | -spectral    |
           | -temporal    |
           | -sensoral    |
           | recordings   |
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| Data preprocessing for the    |
| -Reduction of systematic      |
|  and random errors            |
| -Data compression without     |
|  loss of information          |
| -Minimization of the          |
|  cluster dimensions and       |
|  hence maximization of the    |
|  separation capability        |
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| Analysis of the statistical   |
| requirements on the           |
| training areas for maximi-    |
| zation of the separation      |
| capability of the classes     |
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| Analysis of the dimensions    |
| and distances of the          |________________
| clusters for judging the      |                |
| significant separability      |                |
| of classes                    |   .------------------------------.
 -------------------------------    | Supervised classification    |
                  |                  ------------------------------
.--------------------------------.               |
| Formalization of the results   |               |
| of analysis and their auto-    |               |
| mation as a rule of decision   |               |
| -for the searching and         |               |
|  assembling/separating         |               |
|  of training areas             |               |
| -for the computation and       |               |
|  analysis of the clusters      |               |
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|  Unsupervised classification      |            |
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only these are considered, which contain the complete information when being linked together.

In the case of LANDSAT 5 TM these are the first 4 out of 6 transforms. This approach ensures a data compression free of information losses by 33 %.

Training areas

Decisive for the selction of training areas is not the land use to be pre-set, but the multispectral homogeneity of at first unknown recorded areas; these approximatively match homogeneous land use areas. Thus, the definition of training areas covering inhomogeneous types of land use, as e.g. sparsely built-up areas, mixed forest, etc. can no longer be sustained.

Grouping of training areas

By means of statistical test parameters it must be ascertained before classification which training areas have to be grouped before and which others shall be grouped after classification. Only those training areas will be preserved unaltered whose statistic properties are significantly different. Grouping of training areas of seemingly similar use without performing a statistical test is inadmissible in view of the separating capability to be achieved.

Extrapolation

For operational reasons it is appropriate to first select a sub- area from the overall data set, which may cover, e.g. an entire map sheet, to apply to this preselected sub-area the main component transformation, and finally to apply the resulting parameters onto the principal component transformation of the full data set. This approach necessarily has the effect that the results obtained for the test field remain unchanged and are extrapolated to the extended area.

Results

If one follow strictly the implications contained in the aforesaid, one receives e.g. from the separation of different water bodies - doubtless the hardest of all immaginable test cases - the result that independently of the preset safety probability among the water classes a conflict never occurs. With S=99% the hit rate never fell below 93% [Schulz, 1990].

2.1.2 Evaluation of the Geometry

The development of methodical fundamentals finding application in the relative geometric transformation of multispectral images recorded at different times onto each other with the subpixel precision required in the aforesaid, as well as in the determination of a DEM through digital correlation was concluded and tested outside the project using digitized KOSMOS KATE 200 imagery [Bennat and Boochs, 1990]. This method of correlation shall find application also in the OEEPE project under discussion (KFA-1000 images, SPOT-P-data).

The vectorization of linear objects in the case of LANDSAT 5 TM recordings due to the lacking relatively high geometric resolution (SPOT-P data shall follow at a later date). KFA-1000 imagery reduced to 23 cm x 23 cm is used on a trial basis instead, whereby the radiometric (recognizability of objects) and the geometric (planimetric and altimetric precision) properties shall serve as criteria of usability, which have been investigated in the course of preparatory tests.

2.2 Analog Recordings

2.2.1 Recognizability of objects

The photogrammetric-thematic evaluation of KFA-1000 stereo models has been restricted to linear features (transport system, waters). Verification of their recognizability (also in detail) outside built-up areas (represented in Fig. 3 by hachures) with decreasing object width and referred to single groups such as roads (autobahn, federal/state highways, path), railways, and waters (river, brook) was the main item of the investigation. In the junction areas of motorways the resolvability of details (access and exit roads) was a focus of interest. With regard to the contents the result (see Fig. 3) comes nearest to the Topographic Map at the scale 1.200.000. The landscape model contents which may possibly be qualified as still "coarse" could - if need arose - partially be densified through more detail information and higher accuracy by means of a dynamic integration of aerial images of different scales.

Fig. 3 - Vectorized linear objects (roads, rivers, railway routes and outlined buildup area) by photogrammetric evaluation of KFA stereo images, scale 1:100.000.

2.2.2 Geometry

The available elevation accuracy in the photogrammetric evaluation of KFA-1000 stereo imagery was given special emphasis in the course of the preparatory investigations. A first estimate of ± 25 m resulted from the transfer of results of the MC (Metric Camera) experiment, carried out by the OEEPE, to the KFA recording conditions. The absolute orientation using all control points yielded ± 51 m, the double measurement of single points ± 11 m, whereby two bundled adjustements confirmed the suspicion that substantial systematic errors account for this considerable difference in accuracy. As a consequence, it is planned to perform in the near future the modelling of error vectors as well as the software development for real-time correction of the measurement (by the Photogrammetry Department of the University of Stuttgart). Under the aspect of such clearly enhanced preconditions, a considerable increase in accuracy can doubtless be predicted for the foreseeable future.

CONCLUSION, OUTLOOK

Though the overall frame of the project seems still to be rather tight (limited financial possibilities of the OEEPE), restrictions as to data availability, number and size of the applicational fields, etc.) a European project could nevertheless be shaped, at OEEPE level, which should strive for a common superordinate goal by

- the development, applicational and provision of efficient methods
- the integration of international and multidisciplinary activities as well as
- the allowance for particular needs at national level.

Hence, this undertaking offers the unique chance of laying the foundations for all subsequent tasks in the field of cartography, whereby the underlying overall concept is designed for a stepwise integration of more detailed and accurate information and may at a later date be gradually embedded in a by then more detailed European landscape model excelling by an accuracy inachieved as yet.

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