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The importance of digital orthophotos for sectoral Geo-Information Systems

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ABSTRACT

Digital orthophotos are becoming more and more important as a basic data source for a variety of geo-information systems (GIS) applications. With the availability of high performance computers and peripheral devices for scanning and plotting of aerial photographs this new product 'digital orthophoto' will change the application domain of GIS and will open its application for a lot of users currently working with maps and analogue aerial imagery. This contribution illustrates the use of orthophotos for different GIS application sectors. In addition an example shows a land use classification of a digital CIR-orthophoto mosaik with a multispectral classification enhancing the quality through the integration of other GIS data sources, e.g. parcels, soil types etc.

1. INTRODUCTION

1.1 Sectoral geo-information systems (GIS)

GIS are used in daily practice in many different disciplines. It is this interdisciplinary and integrating atmosphere that makes GIS applications interesting. Because of this variety of application fields the demand for data, functionality and system characteristics differs tremendously. D. Fritsch (1992a, 1992b) tried to classify the different GIS sectors based on their practical applications and importance for the GIS market. As 'sectoral GIS' he identifed five major groups:

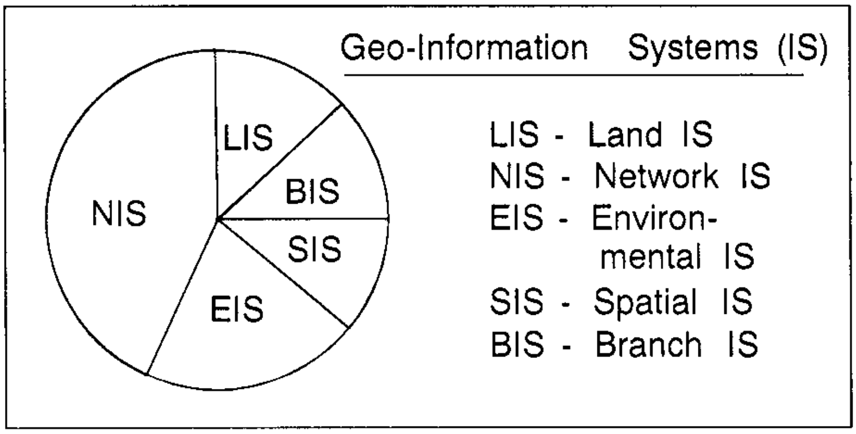

Figure 1: Sectoral GIS (taken from D. Fritsch, 1992b).

- Land information systems (LIS): LIS is an achronym used in the surveying disciplines to identify their activities to set up land registration systems, multi-purpose cadastre, topographical information systems and automated mapping (AM) systems. Nearly every european country is currently establishing such systems in digital form. An overview on these activities is given in R. Bill and D. Fritsch (1993). In Germany national programs such as ALK, ALB, ATKIS, MERKIS and TOPIS are to be named here. These governmental organisations started early in using GIS technology. The LIS domain covers about 10% of the overall GIS market (D. Fritsch, 1992a, 1992b); they are mostly vector-oriented. Hybride GIS applications are to be seen in the data capture (scanned maps and digital orthophotos) and data presentation (combined raster-vector cartography) part.

- Network information systems (NIS): Especially utility companies fairly early transferred the mapping and data maintenance of their facilities into a digital environment. In their application domain the AM/FM (Automated Mapping/Facility Management) idea was created. The supply of their customers with electricity, gas, water, television etc. is more and more going to be managed and mapped with GIS means. The applications are again vector-based with about 40% market share (D. Fritsch, 1992a, 1992b). For data capture purposes raster based heads-up-digitizing grows in importance.
- Spatial information systems (SIS): Geography, planning and engineering disciplines are dominating the geographic or spatial information systems area. Urban and regional planning, demographical or statistical investigations are carried out with the aid of GIS. Because of the wide variety of scales and the diversity of thematic data covered with those applications a clear indentification on the major geometric data type is not an easy task. Vector, raster and even hybrid data are found in this field which stands for about 15% in the GIS market (D. Fritsch, 1992a, 1992b). Very often this sector runs GIS on PC's as platform.
- Environmental information systems (EIS): The protection of our environment against human and natural impacts is becoming more and more important. GIS is a valuable tool for environmental monitoring and mapping and for the analysis of impacts of human planning activities. Agricultural and forestry monitoring and the analysis of habitat of endangered species are also to be named here. Resource documentation and exploration, soil investigations, hydrological and geological applications and many other geo-scientific examples relate to EIS. Scales may vary depending upon the responsible organisation the work is carried out for -- from municipalities to the United Nations (UN). Thus, vector and raster data as well as hybrid data are in use. The application domain is growing and stands for 20% of the overall GIS-market (D. Fritsch, 1992a, 1992b).
- Special branch information systems (BIS): A wide variety of applications remains which does not fit into the before mentioned categories. These are specialized single-purpose GIS such as traffic guidance systems, telecommunication and radio station planning systems, corporate information systems for the private sector, military applications and others. Again the diversity does not allow to clearly identify a dominating role of one or the other geometric data type. More and more of these specialized usages are coming with the availability of low-cost and high-performance GIS leading to approximately 15% of the total GIS market share (D. Fritsch, 1992a, 1992b).

According to D. Fritsch (1992a) in the nineties the ratio of purely vector-dominated applications against hybrid applications is about two to one. Purely raster-dominated applications will move towards hybrid applications. Nevertheless there is strong trend of low-level integration of raster based information (eg. background layer) such as satellite images, scanned maps, and digital orthophotos into vector-dominated applications.

1.3 From analogue to digital orthophotos

Photographic imagery is in the presence of the variety of information, that may be achieved from it, a very cheap and economic way of data capturing. An orthophoto is a photographic image that has beendifferentially rectified to remove any distortion due to recording geometry (position and tilt) and relief displacement. An orthophoto may then be used as a map. For the step of differential rectification the camera position, tilt angles and distortion need to be known to re-establish the central projection and to calculate ground positions from image coordinates. Furtheron a digital terrain model is needed to correct the image distortions caused by relief displacement. Thus, orthophotos are giving benefits, both for interpretation and for geometric and cartographic aspects. Analogue orthophotos are used in many countries to support classical mapping tasks. Black and white or coloured orthophoto maps as well as rectified satellite imagery maps are favoured in various applicationsespecially in mapping, planning and environmental disciplines. Reasons therefore are the non-interpreted content of the imagery, the better readability of orthophoto maps compared to line maps, its higher similarity with the landscape than traditional analogue maps, and further reasons. Analogue orthophoto maps are produced simultaneously to standard map series in various developped countries. They are easy to produce and they might be produced demand-driven. The production of analogue orthophotos has reached a high level of development leaving only some minor problems (such as the multiple z-problem for bridges) unsolved. Long years of experience exists in this field.

With the availability of image scanners, high-performance computers and plotting devices there is an increasing interest to replace analogue orthophotos by digital ones. The technical equipment to produce and to use digital orthophotos exists nowadays. High performance graphic workstations with more than 32 MByte RAM, GBytes of disc storage, graphic processors with 32 bit driving screens with a resolution better than 1000*1000 pixels are available at an acceptable price range. Image scanners and electrostatical plotters and other peripheral devices are on the market. The resolution of image scanners reaches about 3500 dpi, a pixel size of 7.5 micron. Black and white and coloured images may be scanned with high radiometric quality (256 grey values per channel) and stored in up to 3*8 bit (GIM, 1993). Electrostatical plotters from small to large scale formats show a resolution of more than 400 dpi to 2000 dpi (AUTOCAD, 1992). High quality peripheral devices for scanning and plotting are fairly expensive today, low quality devices developped for completely different things such as DTP may in certain cases be sufficient especially for the research area (M. Cramer, R. Bill and M. Glemser, 1993).

In the software field three classes of programmes may deal with orthophoto production: hybrid GIS, digital image processing systems and remote sensing packages. All of them have reached a high level of performance and each of this software products is in principal able to produce orthophotos. The more overlap exists between the three categories the more flexibility and functionality is offered for digital orthophoto production and other tasks such as feature extraction, image interpretation, map updating. Digital photogrammetric systems are a new category in this area, which should try to become the union of hybrid GIS, image processing systems and remote sensing systems. One of the tasks that could be solved with these digital photogrammetric systems is the digital orthophoto production. In the very end digital photogrammetric systems offer the same, and for some specific tasks better, functionality than todays analytical plotters. This is especially valid for procedures able to be automized such as the measuring of fiducial marks for inner orientation or the creation of digital terrain models. Further research is needed for object extraction (e.g. linear phenomena such as roads) and object classification (e.g. image analysis and understanding).

After some years of research (see for instance J. Wiesel, 1985, F.-J. Behr, 1989) and a period of stable production digital orthophotos are now easy to produce even with standard workstations and standard GIS tools (J. Höhle, 1992). With digital techniques some of the problems analogue orthophotos had will be easy to overcome: high production speed, improved image quality, high accuracy and stability, renounce ofopto-mechanical units. Advantages of digital orthophotos are flexibility, short production rate and low costs, if all additional data are available. They are easy to manipulate in radiometry and easy to overlay with other geometric information. For further advantages see also E. Baltsavias, 1992, C. Loodts and G. Steenmans, 1993.

With the progress in photogrammetric research position, tilt and DTM information is becoming available nearly on-line by using GPS (see H. Schade and J. Kilian, 1993) simplifying the aerial triangulation and DTM creation tremendously. On the other hand digital terrain models can be extracted from digital imagery using least-squares- and feature-based matching techniques. A digital orthophoto comes as a by-product of this automatic DTM creation. Thus, many of the hindrances in making use of orthophotos will vanish in near future.

2. THE DIGITAL ORTHOPHOTO - AN IMPORTANT SOURCE FOR GIS

2.1 Digital orthophoto production

The production step of digital orthophotos has three major parts (J. Höhle, 1992, C. Loodts and G. Steenmans, 1993) (Figure 2), which should be discussed here in more detail, because of its impact on the use in sectoral GIS. For further details on digital orthophoto production e.g. cost and mass production the reader is referred to H.P. Bähr and J. Wiesel, 1992, I. Colomina et. al, 1992 and A. Gerhard, 1992:

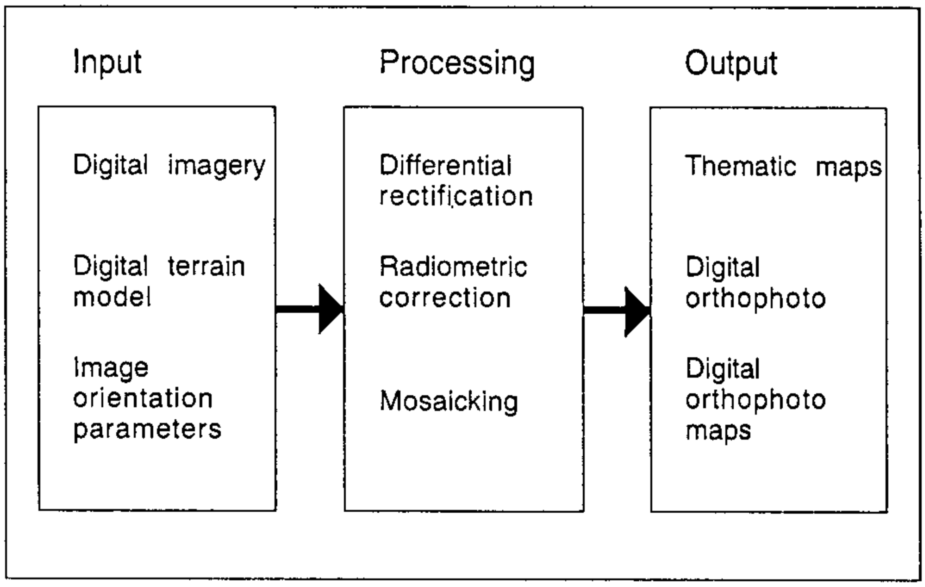

Figure 2: Production steps in digital orthophoto creation.

- Input of data: For the production of digital orthophotos the input needs to be available in digital form. Analogue images have to be scanned with high precision, the image orientation needs to be established by photogrammetric means and a digital terrain model has to be known. Beside the fact that each of these steps today is well known in photogrammetric practice and some steps are even able to be automized, the necessity of preparing these input data in digital form causes problems for many GIS users. Whereas the LIS domain is experienced in photogrammetric procedures, the other sectors are not. Thus, missing experience, high price of scan equipment and the lack of DTM data may keep some sectors stay away from digital orthophoto technology. Success of digital orthophoto techniques highly depends on the automatisation of some of these processes.
- Processing of data: With todays state-of-the-art-systems the processing of digital imagery seems to be fairly easy and cheap (J. Höhle, 1992, H.P. Bähr and J. Wiesel, 1992). Who should not be able to spend less than 100,-DM for a coloured orthophoto? Nevertheless the quality of digital orthophotos depends on experience. The selection of the methods to do the differential

geometric rectification (neighbourhood, bilinear, bicubic etc.), radiometric correction and mosaicking (overlapping band, least-squares-approach) has major impact on computing time, amount of data and influences the result, the digital orthophoto. Acceptance for digital orthophotos may only be reached when it is possible to standardize the procedure, that should run on standard hardware equipment.

- Output of data: The digital orthophoto may either be plotted, i.e. again converted in an analogue form, or transferred via storage media to be used in digital form. Whereas plotting of digital orthophotos asks for cartographic experience (G. Schweinfurth, 1985) especially when combined with thematic vector data from GIS to create thematic orthophoto maps, digital transfer ask for exchange standards. Both aspects may not cause hindrances for LIS users to use digital orthophotos, but other GIS sectors may wait until standard equipment exists for orthophoto output. Especially in the sectors SIS, EIS and BIS usually low cost output devices are preferred, i.e. prices of electrostatical plotters may also prevent users from generating digital orthophotos.

2.2 Sectoral GIS and their current data sources

In the following the sectoral application domains are classified according to their major data sources. Furtheron it is explained what digital orthophotos could do for these applications. The approach taken here separates the application domain based on the scale range where standard applications are carried out. Secondly the various data sources and geometric data capture methods are considered such as surveying, maps, imagery and others.

Sectoral GIS Property	LIS	NIS	SIS	EIS	BIS
Scale space:					
<5000	+	+	-	+	+
25000-50000	+	o	+	+	+
>100000	+	-	o	+	o
Data source (today)					
Surveying, Measuring	+	+	-	o	-
Map digitizing	+	+	+	+	+
Aerial imagery	+	-	+	+	o
Satellite imagery	o	-	+	+	o
Others	o	o	+	+	o

Table 1: Scale space and data sources in sectoral GIS.
(+ = major source, o = source, - = seldom source)

Digital orthophotos are spanning the scale space from 1:500 to 1:50.000 (J. Loodts and C. Steenmans, 1993). Taking satellite imagery into further account the scale space could be expanded to at least 1:200.000. This means digital imagery may become a valuable source for nearly all of the standard applications.

Looking at this table there are at least three of the five sectoral GIS units that are currently using aerial imagery either for photogrammetric stereoplotting or aerial photo interpretation. Especially these groups will benefit from digital orthophotos in both of the mentioned categories. Those who are mainly interested in geometric data acquisition for map producing such as the LIS community should expand their services for land use maps etc. Regional planners, environmental monitoring disciplines currently using the aerial imagery for manual interpretation in conjunction with maps could improve the geometric quality of the interpretation and could combine two separate steps (photo interpretation and drawing on maps, map digitisation) into one integrated step. This will be illustrated by the example at the end of the paper. In addition the two remaining sectors will benefit from digital orthophotos as background maps for heads-up digitizing replacing conventionally digitized maps or scanned maps because of its better readability.

2.3 Digital orthophoto as a source for sectoral GIS

In this chapter six categories are identified and discussed how to apply digital orthophotos with respect to the sectoral GIS applications. In addition there are a lot of other possibilities named in G. Loodts and C. Steenmans, 1993, E. Baltsavias, 1992.

- *Digital orthophoto map production* is a standard technique today, that can be used in various disciplines. For a lot of applications the addition of layers of thematic information might be of interest. This orthophoto map may deal as a backdrop simply for visualization.
- Because of their geometric properties digital orthophotos already become a valuable tool for *data capture and map revision.* For data capture geometric information is measurable and non-geometric information (e.g. number of highway lanes) is addable to a database. Orthophotos can be used for map revision and quality control, for the verification of other data capture methods, for the control of completeness and last but not least for the control of changes. Errors made with other data capture methods are immediately to be seen on an orthophoto.
- Color discontinuities in different images because of different weather conditions, vegetation, phenology or lightning conditions disappear with the application of radiometric calibration algorithms that were especially developped for mosaicking. The homogeneous images thereby become more comparable for *change detection and visualization* over time. The change detection itself can either be applied with digital image processing routines or carried out manually. Hence changes can easily be highlighted, calculated or classified.
- Orthophotos are used for draping of images over synthetic 3D-perspectives for simulation or animation purposes. With stereo-orthophotos a new range of *3D-applications* is offered because they are fully complementary to orthoimages (J. Loodts and C. Steenmans, 1993).
- Because coloured digital orthophotos are multiscale, -spectral and -temporal (J. Loodts and C. Steenmans, 1993), they can be treated like other remote sensing data. *Multispectral classifications* add a new layer of information onto existing GIS. By integration of other data sources, texture information, and available ground truth data to the classification new methods and results evolve.
- With the growing demand for orthophotos land survey departments will switch from analogue to digital orthophotos to form national digital reference data bases. In the U.S. digital orthophotos are produced to form a *digital archive* as base map for data capture, data organisation, and data sharing of natural resources on the county level (for technical details see E. Baltsavias, 1992). The digital approach reduces redundancy and due to its multiscaling properties the user can extract data within the desired extend, scale and resolution.

Sectoral GIS Orthophoto as a source for	LIS	NIS	SIS	EIS	BIS
Orthophoto map production	+	-	o	+	-
Data capture/ map revision	+	+	+	+	o
Change detection/ visualization	+	+	+	+	+
3D-application/ visualization	+	+	+	+	+
Multispectral classification	+	o	+	+	o
Digital archives	+	o	+	+	o

Table 2: Digital orthophoto as future source for sectoral GIS.
(+ = often used, o = used, - = seldom used)

Sectoral GIS benefit differently from digital orthophotos, some benefit from the advantages of a background for visualization or as a background for data capture, others utilize them for change detection, thematic map production or as a new interpretation media. This should be discussed in the following enumeration:

- LIS: Currently map production relies on analogue orthophotos. In future digital orthophotos will be used for both, map production and map map revision. The scale range of 1:500 to 1:50.000 is coverable with digital orthophotos, i.e. the frequently used maps in developped countries in Europe can be updated with digital orthophotos at hybrid GIS. The advantages in the LIS community is their experience with photogrammetric procedures and the availability of DTM and other orientation data. Predominant applications include data capture, map revision, maybe semi-automated in the future, and the build up of national reference archives. 3D-visualization and classification might be applied for special tasks.
- NIS: NIS benefit from digital orthophotos by updating and revising thematic and construction information in areas where no data is available in digital form or not up-to-date. Digital orthophotos are equally important in route planning, for example as a visualization aid in 3D-viewshed analysis.
- SIS: Digital orthophotos will be a big aid for all planners. For example the superimposition of proposed changes onto orthophotos gives planners a new 2D- or 3D-visualization tool for communication between decision makers and citizens on hand. In the field of geography planning and modelling become more realistic with the possibility to integrate the real world into models. Furtheron data capture and interpretation can be improved. SIS users may also be interested to set up digital archives of thematic maps based on digital orthophotos.
- EIS: For EIS users digital orthophoto will become the major source! High geometrical accuracy is especially important for accurate assessment, modelling and controlling of pollutants in the geosphere. Flexibility in scale and time creates new interpretation qualities of digital orthophotos. Environmental monitoring, resource documentation and exploration, change detection and planning will benefit from digital orthophotos. Capture data today, explore and interprete tomorrow for several purposes will become possible. The price of hardware and software is still a problem, more automation is needed for production and handling of digital orthophotos.
- BIS: Because of the heterogenity of this application domain it is not easy to identify the benefits taking digital orthophotos. Some applications may improve the visualization aspects (e.g. radio station planning), others may be able to detect and visualize changes (e.g. traffic guidance).

2.4 Land use classification from digital orthophotos - a pilot study

With the following example the usage of digital orthophotos for SIS and EIS applications should be illustrated. In our opinion these both segments will benefit most from the availability of digital orthophotos. The importance of digital orthophotos as an additional source of data for a GIS in general is unquestioned. Monitoring of dynamic processes like vegetation or land cover is interesting for many sectoral GIS. Multispectral classification for land use/land cover purposes of satellite images is a well studied technique, which is especially useful for small and medium scale applications. The accuracy however is not always satisfactory, because remote sensing images provide a different kind of information which is difficult to match with the classes considered in conventional field mapping procedures. Significant improvements of satellite imagery classification results with the assistance of ancillary GIS-data in vector or raster format are demonstrated in several studies (e.g. L. Janssen, 1990 or G. Sadler and M. Barnsley, 1990).
Conventionally high resolution CIR-photos are used for creating or updating land use or forestry maps etc. Stand alone multispectral per pixel classification of high resolution digital CIR-orthophotos will probably not be compatible to large scale vegetation mapping, but the digital approach allows new applications.

2.4.1 The pilot study

In the pilot study an enhancement of classification quality through the integration of other GIS data sources, e.g. parcels, soil types etc. is demonstrated. The objective is a polygon wise definition of land use and the possible integration into the GIS-data base. Also with the application of GIS-tools a per polygon assessment of accuracy is found.
Upfront a few technical information about the data sources and the equipment. The project is located around 80 km east of Stuttgart, at the egde of the Swebian Alb. The data input for the orthophoto production consisted of 14 low altitude high resolution CIR-photos scanned and radiometrically calibrated with a PS-1 scanner at Zeiss, Oberkochen (W. Mayr, 1992). Natural control points were obtained from maps and from the land surveying department. DTM information with a 50*50 m resolution, and moderate accuracy was taken from the land surveying department. Aerial triangulation data was measured and calculated at an analytical plotter. Processing of the data, by means of differential rectification and mosaicking was conducted by Zeiss, Oberkochen. The size of the RGB orthophoto mosaik is 5060*5060 pixels or ca. 25 MByte per color band. The resolution of the output image is 50*50 cm per pixel corresponding with a map scale of 1:5000 to an overall area of ca. 2.5*2.5 km. The positional accuracy of the orthophoto was +/-1m depending upon the DTM. Furthermore several vector data layers were digitized, e.g. parcels, manual stereoscopic land use classification polygons, topography, soil types, and geological information. Feature data was incorporated in a relational database and attribute data was added. The platform for the GIS-research was an Interpro 2020 Workstation from Intergraph with 32 MByte of RAM and 2 GByte of disc space. The installed GIS software core is MGE/SX. The IMAGER, TERRAIN MODELER and GRID ANALYST modules were used to perform the analysis.

2.4.2 CIR-orthophoto classification versus satellite imagery classification

Compared to the well established technology of satellite imagery classification the analysis of high resolution CIR-orthophotos adresses new and yet unsolved problems, which are illustrated in figure 3. The most interesting questions consider the advantages of high spatial resolution, the influence of mosaicking errors, and a different radiometry:

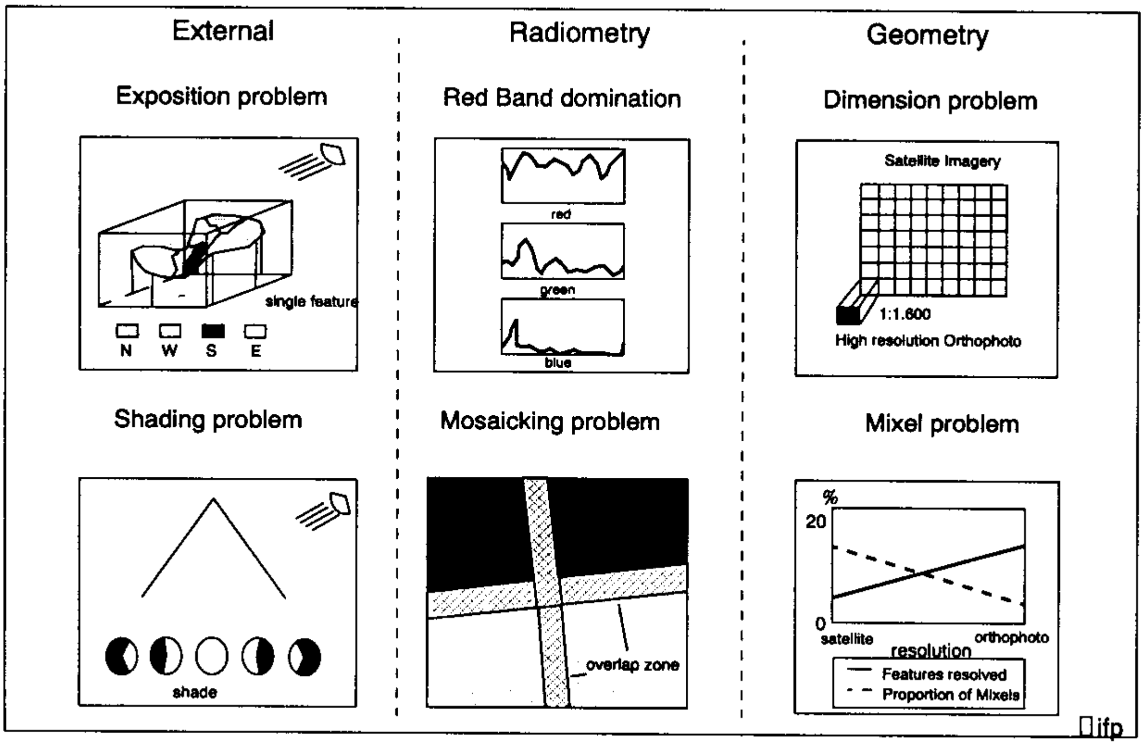

Figure 3: Orthophoto classification versus satellite imagery classification.

- The abundance of morphology causes the most significant distortions within a photo. Areas with a southerly or westerly exposition reflect the surface in much brighter tones than areas with a northerly or easterly exposition.
- Radiometric distortions generally increase from the center of a photo to its edges. Other distortions, which may be neglectable on satellite imagery, are dependent upon the sun angle. Photos taken with a low sun angle display colours and shades significantly different on sunward portions to the sun distant portions of the image.
- Because of the strong reflectance of lively vegetation in the near-infrared during summer time the photos are dominated by a red colour. In a covariance matrix the red input band counted for 85% of all information displayed in the image.
- Mosaicking causes radiometric distortion. Standard techniques are creating a blurry and unsharp transition zone within an overlapping area of two neigboured photos by resampling the grey values according to a determined function.
- The high geometric resolution of digital orthophotos causes a dimension problem. In a satellite imagery (SPOT, 20 m resolution) an image with a size of 1000*1000 pixel for example equates an area of 400 km^2. A digital orthophoto (0.5 m resolution) of 1000*1000 pixels equates to an area of 0.25 km^2. The dimension problem adresses mainly technical questions such as size of training sites, data handling, processing time etc.
- Strongly related to the dimension problem is the problem of mixed pixel elements (mixels). Mixels are pixels that reflect parts of more than one distinct feature creating a composite signature. While the proportion of mixels decrease with finer spatial resolution, the amount and diversity of features resolved increases proportionally. With a spatial resolution 40 times finer than a satellite image new and more detailed features (e.g. single trees) are displayed causing severe classification problems. The newly resolved features are very inhomogeneous (e.g. potatoe field, Lagergetreide) reducing the quality of a classification.

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2.4.3 The classification procedure

The only preprocessing procedures were a minor histogram calibration in order to match the input photos with the output colours of the scanned imagery and a 10*10 median filtering that was found best to smooth the image and to enhance the classification results. The filtering was applied beforehand because filtering after the classification diminishes small but maybe important classes. Compared with manual stereoscopic land use classification techniques and the possibility to differentiate up to 50 or more land use classes, the digital approach of a supervised classification has certain constraints. In order to establish a best suited classification key for an area, the interpreter has to balance between image detail, classification detail and map scale. For classification keys refer to J.R. Anderson et. al. 1976, E. Bierhals, 1988, H. Heitmeyer and D. Schneider, 1991. Generally a hierarchical structure is applied, in which the first level displays broad categories (e.g. forested land) that are applicable for remote sensing data. Categories in the second and third level specify more detailed land use classes or features (e.g. deciduous trees, oak dominated forest).
From visual interpretation only certain obstacles for the supervised classification became obvious, for example:

- A differentiation of cereal classes, with solely spectral characteristics is almost impossible. For example wheat, rye and corn have similar spectral characteristics, their texture however is quite different.
- Manual interpreters silently add 'Lagergetreide' to the surrounding cereal class, with a digital approach a new and inhomogeneous class has to be build. This is especially true for wheat, rye, barley and oat.
- Trees in general and deciduous trees in special reflect a bright red colour on the sunfacing side and a deep black colour on the shady side of the tree.
- Potato fields reflect in two different colours. The heaped areas covered by the potato plants reflect in red. The colour of shady furrows on the other hand ranges from dark red to almost black.
- The colour of meadows varies significantly from darker red to very bright red within the image. The darker tones appear mostly in unmowed meadows whereas the bright tones are reserved for freshly mowed meadows, because in a field the vegetation canopy is composed of many layers of leaves. The upper leaves form shadows that mask the lower leaves, creating an overall reflectance that is formed by a combination of leaf reflectance and shadow (J. Campell, 1987).

Other than in a manual classifications only 10-15 different classes should be adressed in digital classification to minimize misclassifications. The development of a classification key was not so much driven by a hierarchical scheme, but to find as many as possible different informational classes. Beside the above mentioned problems 11 distinct classes (see table 3) were built in a supervised classification. The classification was performed with a maximum likelihood classifier. For the classification results see figure 4.

Category name	Class name
Forested land	Trees
Arable land	Cereals Oat 'Lagergetreide' Wheat 'Lagergetreide' Oat
Green land	meadow-bright (short, freshly mowed) mowed fields meadow-dark (long grains)
Special classes	Streets Unknown NULL-value

Table 3: Land use classes for classification in digital orthophotos.

The results from the error matrix reveal that the non site specific overall accuracy was 94% which means, that in average only 6% of the pixels were outside 3 times the standard deviation of each class. This does however not imply that 94% percent of all pixels were placed correctly in the output image. In comparison to training sites the overall site specific quality in the classified image was about 75-80%.

2.4.4 Classification enhancement with ancillary data

The enhancement of multispectral classifications has long been a subject of research with limited success. Only by adding ancillary data to the classification procedure the accuracy can be improved significantly. A general approach, called the 'Object classification method' by L. Janssen, 1990, is determined, by adding geometrical data to improve the classification. An object thereby is defined as an area where only one land cover type is expected. A fundamental assumption for this approach is the fact, that the majority of pixels within an object is classified correctly.

Based on these fundamentals the enhancement goal in this pilot project was a polygon wise classification of land use where all polygons above a certain threshold are assigned to a land use class or otherwise become a null value. Compositive land use classes such as meadows with irregularly distributed fruit-trees are identified and output as a single class. To satisfy the strong demand of new ways to determine quality, a measurement in terms of per polygon classification quality is created as a by-product.

With GIS-technology different sources of information on various scales are applicable and ready to be integrated. To achieve optimal enhancement the size and scale of the classified objects and the reference data must coincide. An overlay of parcel outlines and TM-Landsat classification, conducted by H.G. Klaedtke et.al. (1992) is only applicable in areas of large parcel sizes. Suspecting a homogeneous land use within each parcel, the minimum size for a parcel to be identified in the classification is 1 ha and a minimum width of 50 m. In areas without land consolidation programmes, a combination of Landsat-TM data and parcels is strainious.

In natural environments on the one hand, vegetation or more general land cover classes largely depend upon physical geofactors such as climate, soil, elevation etc. In cultural environments on the other hand, vegetation or land use classes are mainly man induced. Consequently parcel outlines reveal the strongest correlation to land use boundaries. Correlations of soil data, geology etc. and

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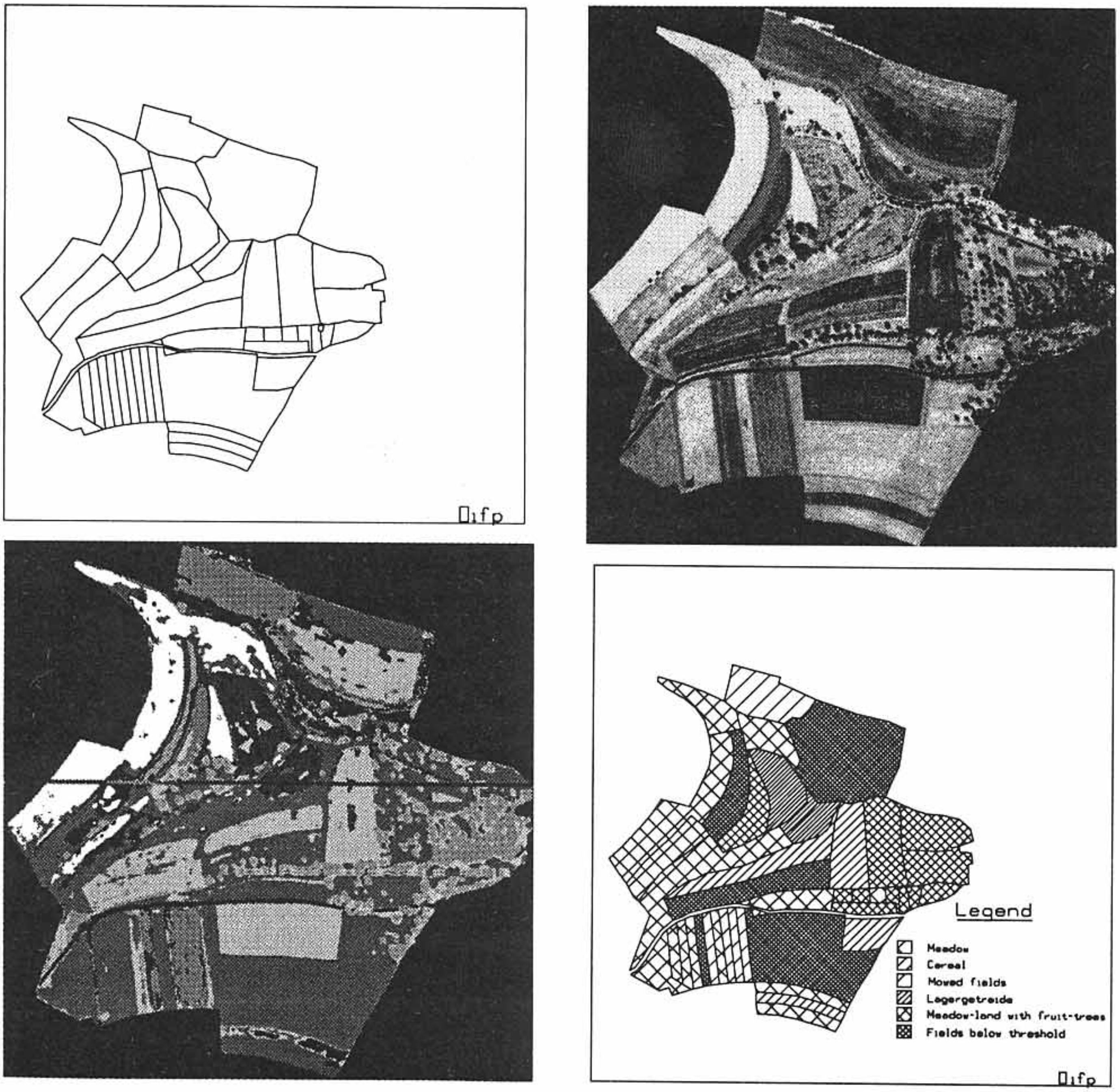

Figure 4: Classification enhancement with ancillary data.

land use are less dominant in the area. In other landscapes other factors (eg. water supply) than parcels may show a stronger correlation. With the detailed, large scale classification of the orthophotos, however parcel outlines appear to be the appropriate object for an analysis overlay (see again figure 4).

To apply raster analysis techniques to vector data a priori vector/raster-transformation is necessary. Thereby the different data layers must coincide in size, scale, orientation and absolute coordinates. This was done with standard tools of Intergraph's software. The research was performed on the basis of the Map Algebra language developped by D. Tomlin (1990), implemented in MGGA - the raster analysis modul of MGE. Map algebra stands for a formalized raster analysis language. The enhancement is performed in four steps, the result is illustrated in figure 4:

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- In a raster overlay of parcels and the land use classification each parcel receives the value of the majority of its land use pixels.
- Quality assessment by adressing the percentage of the majority of pixels within each parcel.
- Threshold operation for a parcel wise assignment of a single land use class.
- Assignment of compositive classes and null values.

The data transfer of the raster attributes into the relational data base is done via a raster/vector-transformation.
From digital high resolution photos one might expect a classification, that is comparable to manual interpretation. This is however not possible, because a hierarchical classification scheme is rather difficult to accomplish compared to manual interpretation. One might also expect that with such a high spatial resolution compared to satellite imagery the spectral response of features becomes clearer making it easier to delineate certain objects or classes. This is however not true either, because the more detailed features are displayed the more mixed responses they create (e.g. potato field). Standard classification of high resolution CIR-orthophotos thereby creates a dilemma to the interpreter, because the advancements in spatial resolution can not be transformed into a superior level of information.

3. DISCUSSION OF PROBLEMS AND RESEARCH TOPICS

At the end the authors will discuss their experience with digital orthophotos and identify the research topics for the future. With the huge amount of data, standard systems have problems to handle data in terms of display time, storage space on the workstation, data processing and data maintenance. If countries want to offer orthophotos in future completely digital further research is needed in methods to store and maintain these national digital orthophoto archives. This includes fast access to all orthophotos in a specified region, orthophoto versions or multiple orthophotos over time and space, data compression methods, meta information systems, quick views etc. It is not the technical equipment setting the limits for this type of application, it is the type of software solutions currently on the market that does not treat or taggle these problems. One can easily expand standard workstations with more than 32 MByte of RAM, GBytes of disc space, high volume archiving systems. This is only a question of money, which is the same for scanning and plotting devices. The major problem is that current software solutions do not offer any support to deal with these amounts of data, neither interactively nor batch. The actual raster data storage methods of flat files, run-length-encoding or quadtree structure to name only a few, are inadequate for mass data storage and display. In raster environments there is a strong necessity for standardisation, in data formats (e.g. TIFF), archiving, quality control and so on, to ensure the availability of digital orthophotos to the whole user community.
Orthophoto production, either analogue or digital, still has to treat two types of severe problems. The geometric problem is related to multiple z-representations in the nature. Building, bridges and even forestry are voluminous bodies and different applications are expecting either to use the projection on the ground or the top of the object. The radiometric problem reflects the currently unsatisfying procedures of image contrast improvements and band mosaicking. Especially for interpretation, classification or visualization the procedure tasks are far beyond from being acceptable.
All the above mentioned topics are to be researched and implemented to offer a user-friendly production system. There is a huge demand for better and more actual map information. Standard mapping techniques are not able to fulfill this demand in time and for a partition in space. Digital orthophotos are able to fill this gap. Still, a lot of further development is necessary to fulfill all market demands.

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