AN INTEGRATED SYSTEM OF DIGITAL MONOPLOTTING AND DTM MODELLING FOR FORESTRY APPLICATIONS

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Abstract

The Chair for Photogrammetry and Remote Sensing of the Technical University Munich has been involved in a project for the development of an operational digital monoplotting system for forestry applications. The project was funded by the 'Bavarian State Institute of Forestry' (LWF).
The paper presents the design and realisation of the developed system. Its efficiency and applicability is illustrated by various examples. Special emphasis is put on the utilization of a high quality DTM for the generation of the orthoimage as well as for the on-line generation and use of DTM products during monoplotting. For revision of forestrial maps the data are extracted from the GIS (SICAD) and transferred into the monoplotting system by conversion modules. In the last part of the paper the potential of the system is discussed. A practical test under productive conditions has been carried out, comparing quality, time consumption and other relevant items with traditional procedures in forestrial mapping. The paper concludes with an overall evaluation of the system and gives some ideas on how it may be used in future.

1. INTRODUCTION

Remote sensing data gained from aerial images and increasingly from digital sensors are an important source of information for forest planing, monitoring and research. The establishment of information systems for forestry applications demands the adaptation of evaluation techniques as well as the integration of digital systems for data acquisition and management. The aim is that the interpretation results obtained e.g. from aerial images are directly imported into the GIS avoiding time consuming and error prone intermediate steps.
Digital monoplotting supplies an efficient procedure to obtain interpretation results digitally in good geometric quality and allows the combination with any other information in vector or raster format. By this means the forest specialist is able to use additional relevant thematic information during the evaluation process.

2. CONCEPTUAL DESIGN AND SYSTEM COMPONENTS

Digital monoplotting is the acquisition of threedimensional information from a single (mono) digital image with the support of the image orientation and a digital elevation model (DTM).
To meet the requirements for the development of a system for forestry applications, one has to take into account, that the operator is a specialist in forestrial image interpretation but not a photogrammetrist. For this reason a system was designed which integrates operational software packages in order to obtain a high operational standard of the complete system (cf. Fig. 1). A comfortable user shell and smooth data flow are indispensable.

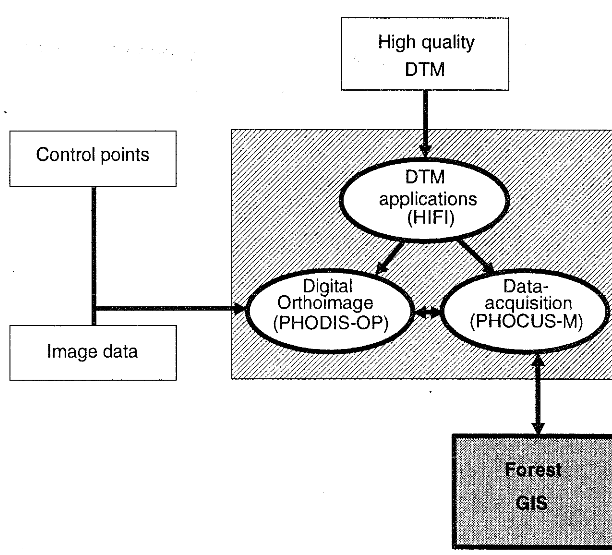

Figure 1 : The structure of the integrated system

Input data for the system are digital aerial or satellite images which have been obtained from scanning analogue photographs or directly have been recorded by airborne or satellite sensors. Either ground control points or orientation parameters e.g. from an aerial triangulation have to be supplied for exterior orientation. Furthermore a digital terrain model (DTM) has to be given for the generation of the digital orthoimage and further use during monoplotting.

The software package PHODIS-OP (Mayr, 1993) from Carl Zeiss is used for the generation of the digital orthoimage. PHODIS is the photogrammetric base for image conversion, interior and exterior orientation, orthoimage generation and mosaicing.

Since the quality of the DTM directly effects the geometric quality of the orthoimage the HIFI-GIS interface (Ebner et al. 1990) was integrated which allows for direct access and rigorous use of high quality DTM generated with the DTM program package HIFI (Ebner et al. 1988).

For data acquisition from the orthoimage PHOCUS-M (Braun, 1989) from Carl Zeiss is used. It enables the operator to acquire threedimensional data structured according to an object code table. In order to ensure a smooth data flow between the forestrial GIS and the monoplotting system and vice versa an optimal adaption of the data structure of PHOCUS to the forestry GIS has been realized. The data exchange between both systems is carried out by interface programs. Under the shell of PHOCUS-M various DTM products can be derived and directly superimposed during monoplotting. This possibility allows for a DTM supported evaluation of the scene.

3. GENERATION OF HIGH QUALITY ORTHOIMAGES

The quality of the DTM has an essential impact on the accuracy of the orthoimage and therefore on digital monoplotting in general. Therefore, it is necessary that the DTM data structure is able to model the terrain surface in a way that topographic features like breaklines are considered. Furthermore it has to be ensured that this DTM structure is taken as the base for the rectification process without a loss of accuracy. The DTM program package HIFI uses a combined grid/tin datastructure and therefore is appropriate for this task. The HIFI-GIS interface in a first step loads this DTM structure into the memory of the computer. For the rectification process the terrain height (z) of each individual orthoimage pixel is computed from this DTM and transferred as a profile for an orthoimage row (cf. Fig. 2).

The accuracy improvement of the implemented procedure in comparison with the standard version of PHODIS-OP (which allows the use of a grid DTM only) is documented by an example. The orthoimage of a mountainous area has been computed as explained above and also with the standard version of PHODIS-OP. Afterwards the orthoimages have been combined with the result of a photogrammetric evaluation (contours and breaklines). Figures 3a and 3b show the results obtained with the use of the high quality DTM and the standard DTM, respectively. The displacement of the breakline in figure 3b (in the order of 5-8 m) is obviously caused by the DTM without consideration of the breakline.

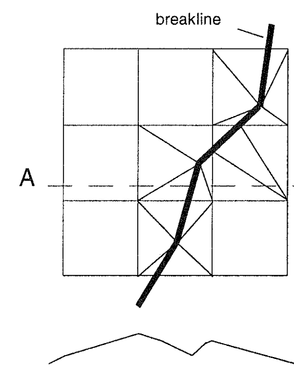

Figure 2: A section of a transferred profile for an orthoimage row

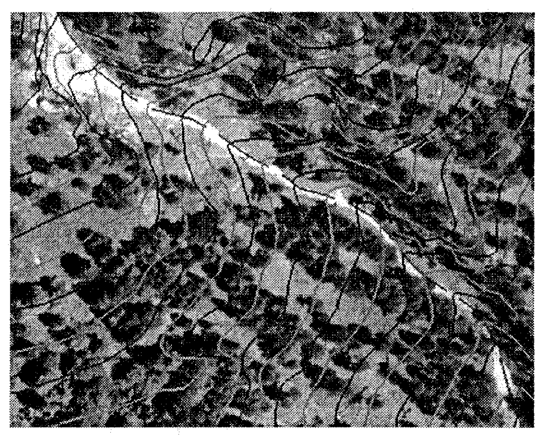

Figure 3a: A section of a high quality orthoimage, superimposed with a photogrammetric evaluation

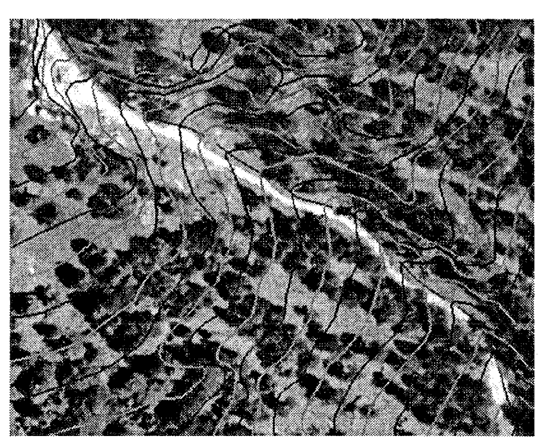

Figure 3b: Same as Figure 3a but orthoimage without consideration of breaklines

4. REVISION OF FORESTRIAL MAPS BY DIGITAL MONOPLOTTING

Verification and revision of forestrial maps based on aerial images and orthophotos is considered as an appropriate tool in forestry (Pröbsting,1994). Even monoplotting procedures based on analogue images have been introduced (Schneider, Bartl, 1994).
The proposed approach is purely digital and therefore allows the forestry expert to interpret and record changes, damages or other phenomenas with high geometrical accuracy by superimposition of image and vector data on the screen of a workstation. Image enhancement tools (contrast, brightness) or zoom functions may be applied during the evaluation.
On the other side an efficient exchange of data between the forest-GIS (SICAD) and the monoplotting system (PHOCUS) is required. Within the project the exchange procedure of digital forest data was realized first for the 'Forest-Management-Map', which is a product of the forestrial GIS. At first, all elements of the forestrial map have been implemented in the PHOCUS object code table. Since PHOCUS manages and stores the objects without their graphic representation, it was necessary to adopt the graphic-code table and the related symbol construction and execution tables in a way that an identical representation of all features under SICAD and PHOCUS was achieved.
With the program package GDBPHO, developed by Schubert & Partner, SICAD-datasets can be transferred into the PHOCUS exchange data format PHODAT by means of a transfer table. Afterwards the data are stored into the PHOCUS database and represented together with the orthophoto. Now an efficient recording can be done by a comfortable usershell, which offers all features of the forestrial map on a screen menu.
In Figure 4 a section of a Forest-Management-Map is presented under PHOCUS environment.

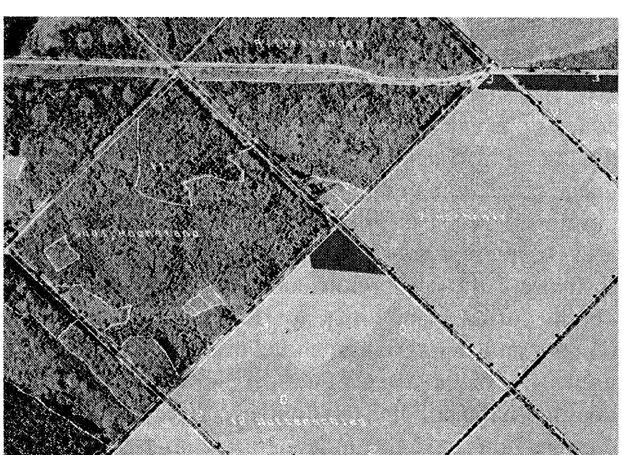

Figure 4 : Section of a forest management map during map revision under PHOCUS environment

The data from the forestry GIS have been superimposed to the digital orthophoto. Because of the colour-filled areas of the map, the orthophoto is not visible in this areas. Therefore an option is offered to clear the colour-filled areas. The deletion of the colour-fill is nothing but a different graphical representation. Each individual areal object still can be identified correctly.
Also other forest maps like the 'site map'or 'slope lability map' were transferred into PHOCUS. These datasets were imported from the GIS-System ARC/INFO.

5. DTM SUPPORTED MONOPLOTTING

The high quality DTM which was already used for digital orthoimage generation is a valuable source during the evaluation process with monoplotting. First of all it is used to calculate the terrain height (z-coordinate) for any point which is measured in the orthoimage. Furthermore it is the base for the calculation and on-line use of different DTM products during monoplotting. For this reason the user shell of PHOCUS-M has been modified in order to allow the operator to derive the products within one and the same environment.
As vector products contour lines and slope and aspect information represented as arrows turned out to be useful especially for forest sanitation projects in alpine regions (see section 5). Figure 5 shows an example of an orthoimage superimposed with contours and aspect arrows. The length of the arrows represents the slope value.

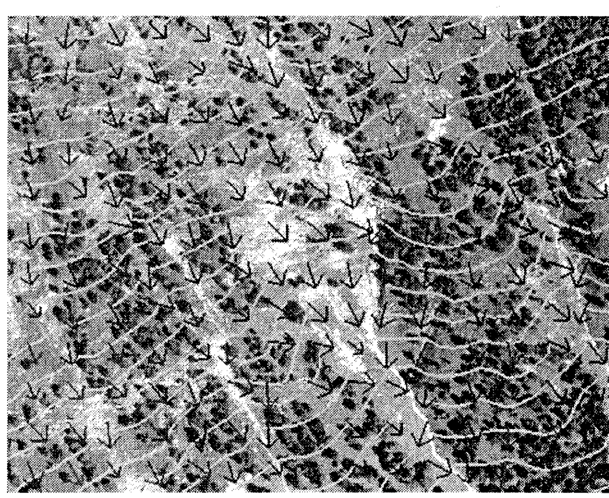

Figure 5: Orthoimage with superimposition of derived contours and aspect arrows

Also products in raster format like colour-coded height-, slope- and aspect-classes or as shaded relief representation are offered. Usually these products are used to pre-determine areas of interest (e.g. catchment areas for soil erosion). These areas are digitized on the screen and afterwards superimposed with the orthoimage for planing restauration arrangements.

6. APPLICATIONS AND EXPERIENCES

6.1 Revision of the Forest-Management-Map

The system was tested by foresters within map revision projects in lowland and in highland. In a first step a high quality orthoimage was generated using the hybrid data structure of HIFI. Then the existing data set of the Forest-Management-Map was extracted from the forestry GIS (SICAD) and transferred into the PHOCUS data base. After superimposition the operator was able to detect the changes in the forest population by comparison of the digital orthoimage and the original map.
Although only black and white images at a scale of 1:15000 were available for the testareas, it was possible to recognize changes in forest stands parcels, tree stock descriptions, homogeneity of population and age structure.
With the use of colour infrared images interpretation is more efficient , so that even the degree of damage could have been determined. It is not possible to extract information about the rejuvinescence of the population less than 2m in height. As a fact of monoplotting of course height of trees cannot be measured.
The changes were edited in the original data set in the PHOCUS environment. PHOCUS offers a feature to set a distinguishing tag on all objects which have been edited or recorded during map revision so that only the revised objects have to be transferred back to the forestry GIS (SICAD).
A print-out of the revised map superimposed with the orthoimage proved to be a very good "work map" for verification in the field. After field verification the changes again were edited in the monoplotting environment. This "three step approach" turned out to be adequate and the acceptance by the foresters was quite good. Up to now the revision of the forestrial maps is done by field verification only, correcting the analogous maps. Although field verification is still indispensable, the preparation for an efficient field work and the revision via digital monoplotting is substantially easier. For example the contours in the highlands were very useful during field verification. Beyond that the forest population was reliable identified from the digital orthophoto, therefore the corrections in the field were reduced considerably.

6.2 Inventory by Spot Checks

Spot check inventory usually is carried out in the following way: The area to be inventoried is covered with a regular grid. Within a defined circle around the spot check point all trees are registered with their type, crown diameter, and damage class.
With the developed system it is possible to superimpose the inventory grid and the investigation circles with the orthoimage. Now the inventory can be performed easily on the screen using the zoomed colour infrared orthoimage (cf. Fig. 6). For field verification the combined print-out of orthoimage and inventory grid is an excellent tool to locate the position of the check spot in the field and to verify the results on the spot. Especially in the highlands the preliminary inventory map is very useful to locate the check points. Different tests of this two stage approach have proved to reduce the time consuming investigation in the field remarkably.
Usually the inventory is repeated in regular time intervals (e.g. annually). In this case, the former inventory can be visualized on the orthoimage and changes of the state of the individual trees and crowns can be detected and revised correctly. A pure crown mapping by means of the digital orthophoto also is possible.

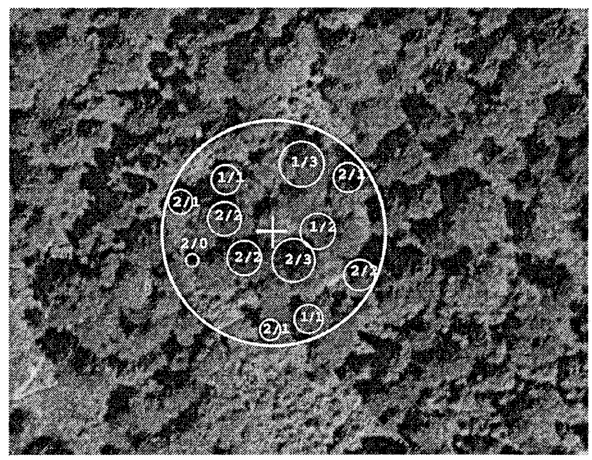

Figure 6: A spot check for forest inventory

6.3 Sanitation of Protective Forests

Especially in alpine regions the forest is of great importance to protect settlements and traffic facilities from avalanches or damages caused by soil erosion. Therefore an important field in forestry is monitoring and sanitation of so called "protective forests". If the forest cannot fulfil its natural function of protection, replanting or man-made constructions have to be planned.
The digital monoplotting system was also tested for this task. In a first step the DTM products contours, colour coded slope and aspect maps were derived from the high quality DTM. Since the superimposition of DTM raster images causes an erasing of the orthoimage, a tool was developed which allows the operator to vectorize the areas of interest interactively by screen digitizing.
In figure 7 the orthophoto and the demarcated areas obtained from a slope map are shown in superimposition. In a similar way colour coded exposition maps were used. Now these "areas of danger" were investigated in detail with the use of the orthoimage. Specific actions or constructions have been planned directly on the screen using a "toolbox" of the most common damming operations.

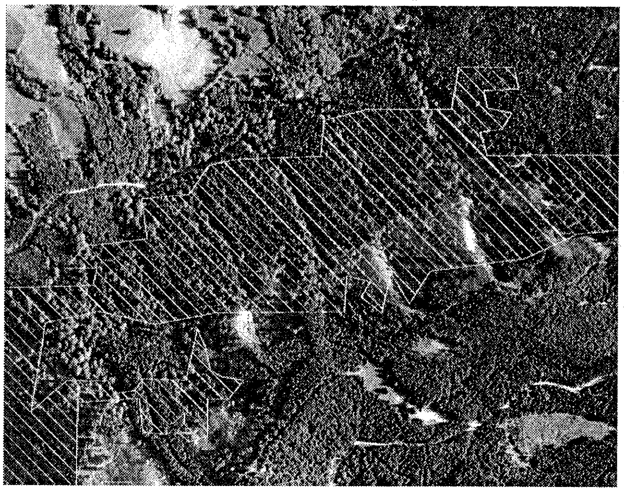

Figure 7: Section of an orthoimage superimposed with "areas of danger".

7. CONCLUSIONS

By integrating software packages for DTM modelling, orthoimage generation and photogrammetric data acquisition an operational digital monoplotting system has been developed. The specific requirements of forestry applications have been taken into account and a user shell has been designed regarding the fact, that an operator skilled in forestry can handle the system.
Practical tests have shown, that the system is suitable and efficient for different applications in map revision, forest inventory and forest monitoring. The utilization of a high quality DTM for orthoimage generation and evaluation has proven to be adequate.
Verification of the interpretation results in the field is still necessary but can be reduced considerably by applying the system.

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