DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM WITH THE AID OF DIGITAL IMAGE PROCESSING TECHNIQUES

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ABSTRACT
The mutual effect of economical activities, tourism and landuse on the state of the natural system were studied in a testsite around Davos, Switzerland. In a first step, field work was carried out to yield a reliable data base. The multidisciplinary venture covered various fields including geomorphology, soil science, climatology, geobotany, forestry, game biology and landscape history. All spatial information was collected in a Geographical Information System (GIS). Image processing techniques were extensively used to digitize the incoming survey maps and to control the consistency of the data. On the basis of a mathematical model natural elements such as soil type, vegetation type, agricultural yield, game dispersal, avalanche hazard, etc. have been simulated. Furthermore, several scenarios have been investigated showing contrasting concepts for landuse. This resulted in a series of thematic maps (e.g. productivity, avalanche hazard maps). These maps can be displayed for interactive examination using digital image processing facilities.

Keywords: image processing techniques, Geographical Information System, scenario, modelling

1. INTRODUCTION
Switzerland agreed to participate in UNESCO's worldwide research program "Man and Biosphere" (MAB) by contributing to its mountain program MAB-6 "Man's Impact on Mountain Ecosystems". One of four national MAB-projects surveyed an alpine testsite near Davos, about 100km² in size and within an elevation range from 1500 to 3200m.a.s.l.

Fig. 1: Information layers forming the Geographical Information System MAB-Davos (Ref. 2)

The research project MAB-Davos aims to quantify the spatial interactions between the various forms of landuse, such as agriculture, forestry and tourism, with the natural, biotic and abiotic environment (Ref. 6).

Consequently, the situation for the year 1982 was deduced deterministically using data of the biotic and abiotic environment and of the landuse. This requires for a model which combines all of the relevant entities of the region.

The following disciplines contributed to the project (Fig. 1): Geomorphology, Climatology, Forestry, Game Biology, Landscape History, Soil Science and Vegetation. In addition, a snow cover depletion map derived from remote sensing satellite data has been incorporated (Ref. 3). The physical properties of the testsite were represented by the Digital Terrain Model (DTM).

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We decided to install a specialized information system using the tools which are available for image processing applications. In order to do so all the data to be assembled had to be digitized into a common raster. The resulting data file is comprehended as a multivariate data set.

2. THE GEOGRAPHICAL REFERENCE

As a geographical reference a compulsory perimeter was chosen. Within the area of interest a raster grid size of 50m x 50m was selected and oriented according to the topo-graphic map projection used in Switzerland.

This geographical reference system represents the spatial basis required to relate features which have been collected by different disciplines.

3. APPROACH USING DIGITAL IMAGE PROCESSING TECHNIQUES

The transformation of all incoming information into the same raster format facilitates the use of digital image processing techniques. At the Institute for Communication Technology of the ETH an interactive image processing system has been installed (Ref. 1). A multiuser image display system (Gould-DeAnza IP8500) is connected with a powerful host computer (DEC VAX 11/780).

Interactive image processing enables the user to visualize the different features on the color monitor. The raster files are interpreted as (two dimensional) images and they can then be processed as a multivariate data set.

Extensive software utilities allow point-related and neighborhood-related operations on the different feature planes. It is possible to execute typical image processing steps under user control, such as geometric corrections, binarisation or assignment of user codes.

By applying these utilities the user is able to study the features he is interested in and to compare them with features belonging to other disciplines. Further, his expertise is immediately available for other users.

4. METHODS USED FOR DIGITIZATION

Every discipline involved in the project presented their field survey maps in a different way. The results were available in a variety of scales ranging from 1:2'500 to 1:50'000 with special signatures, symbols and colours. In order to digitize these maps one of the following methods has been used:

Method 1: PHOTO SCAN

The photographical reproductions of the survey maps in a common scale of 1:100'000 have been scanned using a photomechanical drum scan device. The effective raster scan size of 10m x 10m has been generalized after control and correction to 50m x 50m. A schematical diagram of the procedure is given in Fig. 2.

Method 2: POLYGON

Vectorization of the survey units using a digi...
tizer tablet. Vector to raster transformation performs the common grid of 50m x 50m.

Method 3: TABLE
Pointwise collection and assignment using tables for pairs of coordinates and feature codes.

Method 4: DERIVATES
Model-guided derivation of image planes from existing feature planes. A typical example is the computation of the slope plane based on the DTM. It is necessary to compute for each picture element the angle between the surface normal and the direction of gravity.

According to the different disciplines the survey maps contain varying densities of information. Besides true binary entities (e.g. project Game Biology -- occurrence of deer in winter season) very complex surveys are encountered. For example, the vegetation map contains 61 different units occurring at three hierarchical levels.

5. ANALYSIS OF THE MULTIVARIATE DATA SET

A combination of selected features from the multivariate data set can be displayed in a map-like form on the color monitor. Data from different levels can easily be combined and visualized to answer simple questionings. More complex questionings can be evaluated using models.

In the project MAB-Davos a set of rules describing the interactions and relations of the different entities contained in the dataset has been derived in order to model "landuse". Based on the expert's vast a-priori knowledge, a hierarchical order of the information layers has been derived as indicated in Fig. 3. Parts of the model were established in an inductive manner, other parts more deductively. The invariant entities as the DTM or the radiation (Ref. 4) are taken separately as given properties of the testsite.

The accuracy of the selected rules was tested by modelling the landuse in 1982 and comparing the obtained results with the actual landuse for the same time period. A detailed description of the model is given in Ref. 5.

After having optimized the individual parts of the model they were assembled to form a comprehensive model. Mathematically it is a static model as the factor 'time' is not simulated explicitly. The simulations describe formal relationships rather than physical processes and they do not give predictions of future developments. They describe possible situations which might occur if the external conditions remain constant.

Fig. 3 shows how features or groups of features are related within the simulation-model. The degree of dependency increases gradually from top to bottom.

With the aid of an image display the spatial outcome of the simulation result can easily be compared with the corresponding survey maps.

6. LANDUSE-SCENARIOS

Changing the external conditions according to contrasting concepts of landuse allows the user to simulate possible states of the testsite. We investigated some scenarios on the basis of the multivariate dataset in order to cover a broad variety of possible political decisions. A detailed description of the concept and the realization is given by Ref. 5.

The scenarios are the most essential aspect within the MAB-Davos project and are therefore briefly characterized as follows:

1. Davos today: Simulation of the situation observed in 1982. Enables us to calibrate the model. Differences with respect to actual survey maps may result from some inefficiencies of the model.

2. Primeval Davos: landscape in original condition, no landuse, testsite uninhabitated.

3. Davos with fully developed touristical infrastructure: Due to increasing urbanization agricultural landuse is shrinking. Unused pastures are covered with scrub and forest. The diversity in wildlife is reduced.

4. Davos developed under nature-preservation: Abandoned pastures are again in use as in 1900, afforestations in regions endangered by avalanches, wildlife finds favorable conditions as touristical interferences diminish.

Fig. 3: Simplified schema of the model structure
5. Davos without forest: assume all forested areas will be used agriculturally. Almost all the valley-floor, including the settlement, is highly endangered by avalanches and torrents. Just a few areas within Davos can be considered relatively safe as they are protected by surrounding buildings. The diversity of wildlife is reduced.

It is now of interest to quantify the impact on the various entities if one of the landuse scenarios would take place. The image processing capabilities again allow map-like output of the resulting state of the landscape. We are getting simulation results on a pixel-by-pixel basis which are convenient documents and support the expert's understanding of potential situations. As an example (taken from Ref. 5) we reproduced in Fig. 4 simulated forest maps. These show how the forested areas would be distributed within the testsite given a few of the previously mentioned scenarios.

![Simulated Forest Maps](image)

**Fig. 4:** Forest-area in the scenarios (Ref. 5)

a) Davos today (actual state)
b) Primeval Davos (potential state)
c) Davos with fully developed touristical infrastructure (assumed to be identical with a)
d) Davos developed under nature preservation; (hazardous regions afforested)

7. CONCLUSIONS

An interdisciplinary venture gathered various data and a specialized geographical information system has been assembled, strictly based on a raster format. Image processing facilities supported greatly the steps of digitization and quality control. In addition we modelled the landuse within the testsite for 1982. We developed five landuse scenarios resulting in a variety of thematic maps. We definitely propose the use of image processing methods for complex applications as in this interdisciplinary approach.

We consider such a multivariate data set as an example for an adequate data base in an information retrieval system. As such it represents a prerequisite for geographical expert systems.

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REFERENCES


