AD A139447

EXPERIMENTS TO CORRECT A DIGITAL MAP DATA BASE USING SCENE ANALYSIS

Principal Investigator

Franz Leberl
Institute for Image Processing and Computer Mapping
Graz Research Center
Wastiangasse 6
A-8010 Graz, Austria

Contract Number DAJA 45-83-C-0022

Contractor

Institute for Image Processing and Computer Mapping
Graz Research Center
Wastiangasse 6
A-8010 Graz, Austria

Fourth Progress Report
Covering the contract period from
1 September - 31 December 1983

The research reported in this document has been made possible through the support and sponsorship of the U.S. Government through its European Research Office. This report is intended only for the internal management use of the contractor and th US Government.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A139447	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Experiments to correct a digital map using scene analysis.		5. TYPE OF REPORT & PERIOD COVERED Progress Report 1 Sep - 31 Dec 83
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Franz Leberl		8. CONTRACT OR GRANT NUMBER(s) DAJA45-83-C-0022
9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute for Image Processing & Computer Mapping Graz Research Center A-8010 Graz, Austria.		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102A-IT161102-BH57-01
11. CONTROLLING OFFICE NAME AND ADDRESS USARDSG-UK PO Box 65, FPO NY 09510		12. REPORT DATE March 84
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rectification, digital images; digital mapping; scene analysis; cartography

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Concepts and methods used in correcting a digital map base with scene analysis are presented in summary form.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

INSTRUCTIONS FOR PREPARATION OF REPORT DOCUMENTATION PAGE

RESPONSIBILITY. The controlling DoD office will be responsible for completion of the Report Documentation Page, DD Form 1473, in all technical reports prepared by or for DoD organizations.

CLASSIFICATION. Since this Report Documentation Page, DD Form 1473, is used in preparing announcements, bibliographies, and data banks, it should be unclassified if possible. If a classification is required, identify the classified items on the page by the appropriate symbol.

COMPLETION GUIDE

General. Make Blocks 1, 4, 5, 6, 7, 11, 13, 15, and 16 agree with the corresponding information on the report cover. Leave Blocks 2 and 3 blank.

Block 1. Report Number. Enter the unique alphanumeric report number shown on the cover.

Block 2. Government Accession No. Leave Blank. This space is for use by the Defense Documentation Center.

Block 3. Recipient's Catalog Number. Leave blank. This space is for the use of the report recipient to assist in future retrieval of the document.

Block 4. Title and Subtitle. Enter the title in all capital letters exactly as it appears on the publication. Titles should be unclassified whenever possible. Write out the English equivalent for Greek letters and mathematical symbols in the title *(see "Abstracting Scientific and Technical Reports of Defense-sponsored RDT/E,"AD-667 000).* If the report has a subtitle, this subtitle should follow the main title, be separated by a comma or semicolon if appropriate, and be initially capitalized. If a publication has a title in a foreign language, translate the title into English and follow the English translation with the title in the original language. Make every effort to simplify the title before publication.

Block 5. Type of Report and Period Covered. Indicate here whether report is interim, final, etc., and, if applicable, inclusive dates of period covered, such as the life of a contract covered in a final contractor report.

Block 6. Performing Organization Report Number. Only numbers other than the official report number shown in Block 1, such as series numbers for in-house reports or a contractor/grantee number assigned by him, will be placed in this space. If no such numbers are used, leave this space blank.

Block 7. Author*(s)*. Include corresponding information from the report cover. Give the name*(s)* of the author*(s)* in conventional order *(for example, John R. Doe or, if author prefers, J. Robert Doe).* In addition, list the affiliation of an author if it differs from that of the performing organization.

Block 8. Contract or Grant Number*(s)*. For a contractor or grantee report, enter the complete contract or grant number*(s)* under which the work reported was accomplished. Leave blank in in-house reports.

Block 9. Performing Organization Name and Address. For in-house reports enter the name and address, including office symbol, of the performing activity. For contractor or grantee reports enter the name and address of the contractor or grantee who prepared the report and identify the appropriate corporate division, school, laboratory, etc., of the author. List city, state, and ZIP Code.

Block 10. Program Element, Project, Task Area, and Work Unit Numbers. Enter here the number code from the applicable Department of Defense form, such as the DD Form 1498, "Research and Technology Work Unit Summary" or the DD Form 1634. "Research and Development Planning Summary," which identifies the program element, project, task area, and work unit or equivalent under which the work was authorized.

Block 11. Controlling Office Name and Address. Enter the full, official name and address, including office symbol, of the controlling office. *(Equates to funding/sponsoring agency. For definition see DoD Directive 5200.20, "Distribution Statements on Technical Documents.")*

Block 12. Report Date. Enter here the day, month, and year or month and year as shown on the cover.

Block 13. Number of Pages. Enter the total number of pages.

Block 14. Monitoring Agency Name and Address *(if different from Controlling Office).* For use when the controlling or funding office does not directly administer a project, contract, or grant, but delegates the administrative responsibility to another organization.

Blocks 15 & 15a. Security Classification of the Report: Declassification/Downgrading Schedule of the Report. Enter in 15 the highest classification of the report. If appropriate, enter in 15a the declassification/downgrading schedule of the report, using the abbreviations for declassification/downgrading schedules listed in paragraph 4-207 of DoD 5200.1-R.

Block 16. Distribution Statement of the Report. Insert here the applicable distribution statement of the report from DoD Directive 5200.20, "Distribution Statements on Technical Documents."

Block 17. Distribution Statement *(of the abstract entered in Block 20, if different from the distribution statement of the report).* Insert here the applicable distribution statement of the abstract from DoD Directive 5200.20, "Distribution Statements on Technical Documents."

Block 18. Supplementary Notes. Enter information not included elsewhere but useful, such as: Prepared in cooperation with . . . Translation of *(or by)* . . . Presented at conference of . . . To be published in . . .

Block 19. Key Words. Select terms or short phrases that identify the principal subjects covered in the report, and are sufficiently specific and precise to be used as index entries for cataloging, conforming to standard terminology. The DoD "Thesaurus of Engineering and Scientific Terms" *(TEST)*, AD-672 000, can be helpful.

Block 20. Abstract. The abstract should be a brief *(not to exceed 200 words)* factual summary of the most significant information contained in the report. If possible, the abstract of a classified report should be unclassified and the abstract to an unclassified report should consist of publicly- releasable information. If the report contains a significant bibliography or literature survey, mention it here. For information on preparing abstracts see "Abstracting Scientific and Technical Reports of Defense-Sponsored RDT&E," AD-667 000.

☆ U.S. GPO: 1974—540-847/9052

1. Scientific Work Done During The Reporting Period

(a) An overview of the concepts developed during the first year of this project, which we name now for short "Photo-Interpretation Expert" PHIX is attached to this report. It contains also a listing of functions of the image processing system DIBAG.

(b) The aerial image material is partly digitized and is available on digital tapes. Preprocessing which compensates for errors due to the scanning process was carried out.

(c) The test of the interface to DESBOD, the map data base and geoinformation system, proved successful so that realistic map data will now be entered.

(d) Experiments for feature extraction for monochrome images, including texture and neighbourhood-related properties, are carried out to select optimal data for object recognition.

(e) The image-to-image registration procedure was extended by a module where ancillary navigation data may be used to generate the anchor point grid for resampling. Geometries may be those of metric cameras (central perspective) or spectral scalling systems. The module includes access to a digital terrain model so that also images of areas with more complicated topography may be considered.

2. Research plans

During the third quarter in the project's schedule the following tasks will be treated:

(a) Test of recognition procedures and segmentation with map data.

(b) Investigations of possibilities to describe general knowledge in the relational data base level of the geoinformation system.

(c) development of raster-to-vector-conversion algorithms for the symbolic description of located objects.

3. Significant Adminstrative Action

None.

4. Other Information

H. Ranzinger presented a paper "Map-Guided Feature Detection in Aerial and Satellite Images" at the Workshop "Pattern Recognition in Photogrammetry" held in Graz, Austria, September 27-29,1983. A paper "A Geoinformation Expert System for Synergetic Use of Map and Image Data" and a poster paper "Combinations of Remote Sensing Data with a Digital Map Data Base", by H. Ranzinger and M. Ranzinger, will be presented at the EARSeL Eighth General Assembly and Symposium to be held at Guildford, England, April 8-11,1984. They will appear in the proceedings and will be submitted to ERO at the appropriate time.

5. Financial Statement

ERO-Support only

Amount received		USS 16 500.-
Personnel (one year)	USS 21 000.-	
Other expenses	USS 1 000.-	
Amount spent	USS 22 000.-	

6. Important Reports Acquired

None.

Graz, 31 December 1983

Prof. Dr. F. Leberl

Attachment to Fourth Progress Report
Contract Number DAJA 45-83-C-0022

Correcting a Digital Map Data Base by Scene Analysis: Concepts and Methods

H.Ranzinger F.Leberl

Graz Research Center

Introduction

The field of applications of computer sciences is rapidly increasing. At the beginning, computers were used in the original sense of the word, namely to calculate numerical problems. Soon the question arose whether these machines were capable of performing "intelligent" tasks which go far beyond purely mechanical procedures. This lead to the emergence of a new branch in science: Artificial Intelligence (AI).

The goal of artificial intelligence is to propose and develop methods which make use of a computer's capabilities to process information similar to biological organisms. Here, one of the information sources is visual perception, with which computer vision in concerned. Computer vision is, after Ballard and Brown (1982), the "construction of explicit, meaningful descriptions of physical objects from images".

Modern imaging systems acquire image-like representations of the world already in digital form. Much effort has been put into information extraction from these data alone and has yielded a solid basis of digital image processing methods. However, human perception of the world involves knowledge, which is mostly acquired by learning and subsequent deduction. The issue in artificial intelligence is therefore to make knowledge in some form also accessible to automata.

Expert Systems And Knowledge

The incorporation of knowledge in a program leads to so-called expert systems. Nau (1983) gives an overview of the concepts involved. The model for problem-solving is stated explicitly in a knowledge-base. This may be termed as propositional or descriptive representation as opposed to procedural knowledge where the program code itself contains the strategies to be taken.

McCalla and Cercone (1983) name the following approaches to knowledge representation

- semantic networks
- first-order-logic
- frames
- production systems

The knowledge-base is manipulated by a separate control strategy. Of course, on a high level, the control structure itself, as it is a program, incorporates again procedural knowledge, namely how to handle the knowledge-base, and thus limits the set of actions which can be made. Thus, today's expert systems are constructed with respect to particular applications, at present predominantly in medical consulting and in natural language understanding.

Specification Of The Problem Of This Study

In this study, we ~~are~~ concerned with one special aspect of the computer vision: How can knowledge in the form of a digital map serve in automatic image interpretation, and, on the other hand, how can interpretation results be used to change or update the map? In a wider sense, "map" may mean any graphic representation of a scene that is imaged. Here, in particular, ~~we~~ deal with maps in the cartographic sense, and with images from airborne photographic systems. One of the obvious applications is the correction or densification of a map data base using time series of aerial surveying imagery.

The aim of this study therefore is the design of a strategy to evaluate the usefulness of image-map correspondence to aid the interpretation of digital aerial photography. This is the first step to be taken towards a photo-interpretation expert system, which we shall henceforth name PHIX.

Aerial photography is one source for the update of cartography. It is acquired on a regular basis, however, the updating for many map series is, as a rule, several years. Support in the interpretation of the imagery can be given by focussing on changes rather than on invariant information. Thus the attention of the human interpreter can be directed to relevant locations in an image and, in a next step, supplying hypotheses about the nature of the inconsistencies between map and image. He then can interactively work on the data indicated and enter his interpretation in a suitable form.

A Review Of Literature

Several efforts have been described in the literature to use a map data base to analyse aerial images.

At the Stanford Research Institute, Barrow et al. (1977), Tenenbaum et al. (1978) or Fischler et al. (1979) used map data to guide feature detection. Roads or coastlines were identified by predicting their locations and thus restricting the search in the image matrix to small areas where elaborate pattern recognition methods could be applied.

Lantz et al. (1978) describe an approach taken at the University of Rochester. A semantic network is used to represent declarative and relational knowledge of the image contents. The nodes in the network describe which procedures are to be performed during interpretation.

At Carnegie-Mellon University, McKeown (1982) and McKeown and Denlinger (1982) report on a semi-automatic image understanding system which relies on a pictorial database, a map data base and a rule base, where the rules have general knowledge about objects of the real world rather than present particular facts about specific objects. A first application - the segmentation of airport scenes - shows the feasibility of this approach, though the very general concept pays - at the current state of available computing power - a heavy computing time penalty.

Havens and Mackworth (1983) from the University of British Columbia describe the Mapsee2-system which uses schema models in a network. Each model represents a class of objects, providing a description of the generic properties of every member of the class and specifying possible relationships of the class with other schemata in the network. With this knowledge, a structural description of the map is provided which guides the segmentation process on an aerial image.

The German Research Institute for Information Processing and Pattern Recognition (FIM) exhibits activities reported by Sties et al. (1977) or Kestner (1980).

Previous Own Work

The project is based on previous work performed under ERO Contracts and ongoing efforts in the development of geoinformation systems. Kropatsch and Leberl (1981) developed a first concept of a relational digital map data base and showed its applicability in map-guided control data acquisition for digital satellite image rectification. Leberl and Ranzinger (1982) extended the idea of map-image-correspondence to aerial digital photography. In both approaches, recognition procedures were implemented to identify objects in the imagery with the help of templates taken from the map data base. The basic image processing algorithms were implemented on a dedicated device (digital video processor). A comprehensive set of primitive image operations was defined which can be, by means of an interpreting program, combined to perform more complex procedures (Ranzinger, 1983). The idea of the first map data base is currently being extended to develop a geoinformation system (Kainz and Ranzinger, 1983).

Layers Of A Computer Vision System

Problem solving in artificial intelligence involves a multiple-layer structure from the top, where a problem is stated, to the bottom, where circuitry in the computer carries out a sequence of primitive operations fixed by the processor(s) incorporated. Figure 1 gives an idea of this layer structure, where upper layers control lower layers and lower layers serve as tools for operations intended by upper layers. This schematic representation is, of course, not complete, but can be detailed at various levels of complexity.

Basically, top-down concepts or bottom-up-concepts can be constructed. However, top and bottom are ill-defined entities. At each complexity level it may be valid to assume all lower layers to be "black boxes" with an interface only existing to the layer immediately below.

In the problem under consideration, we define the layers "scene analysis" and "map data manipulation" as the bottom and eventually will work upwards keeping in mind that an expert system in computer vision is the fir goal. Thus we have to verify that we can make use of too provided by previous investigations.

Tools In Image Processing

The image processing system currently in use is DIBAG, supporting research rather than being a production tool. It incorporates actually two more or less equivalent subsets. One subset is designed to work on general-purpose hardware and therefore is basically portable from one computer architecture to another one. The second subset makes use of

PROBLEM DEFINITION
INFORMATION AND DATA DEFINITION
DATA AND KNOWLEDGE REPRESENTATION AND STRUCTURES
SYMBOLIC DESCRIPTION EXTRACTION
SCENE ANALYSIS MAP DATA MANIPULATION
IMAGE PROCESSING - MAP DATA PROCESSING
IMAGE OPERATORS - GRAPHICS OPERATORS
PRIMITIVE FUNCTIONS
COMPUTER LANGUAGES
DEVICE INTERFACES
HARDWARE / FIRMWARE

Figure 1: Layers of a computer vision system for the exploitation of map - image correspondence

an interactive image processing workstation and is thus hardware-dependent. However, an image processing language has been defined which allows problem-oriented algorithm formulation. Details on the functions of each of DIBAG's components are given in the appendix.

Special applications are implemented at first outside the system itself, but using the conventions regarding data handling. A subroutine library is available which incorporates the basic functions for image access and user interface. Generally applicable algorithms are finally taken over and become standard.

In this study, recognition procedures are of special interest. The original stock of histogram analysis, relaxation and correlation has been extended by a line follower based on gradient magnitude, simualtaneous region growing under restrictions and statistical feature-space classification. Sequences of procedures are bound together to yield new functions by writing "macro"-operations in the control language of the computer system.

Tools In Map Data Processing

Based on the experiences gained from a previously used map data base (Leberl and Kropatsch, 1980) the geoinformation system DESBOD is currently under development.

The system comprises three principal parts: A data compilation system to digitize spatial data and to assign attributes, a map data base system for management and retrieval, and a data analysis and output system. It is primarily intended to be use for environment - related planning and monitoring and for geoscientific research.

The data structures involved are

- graphic elements and
- thematic elements.

Graphic elements are points, lines and regions which are consist of the graphic primitives "edge" and "node". The graphic elements are on the one hand coordinate-related to represent their spatial locations and on the other hand related to one another by their topologic properties such as adjacency or inclusion.

Thematic elements are assigned to the graphic elements thus giving further descriptions of properties of the real-world-objects represented in the data base. Again, relations exist between thematic and graphic elements as well as among thematic elements themselves.

For flexible and quick retrieval, most of the relations are stored explicitly so that various data access paths can be selected. Through this construction, it will be possible to extend the system to a general knowledge-base by adding an additional layer which describes, on an abstract level, interrelations and inferences of thematic elements in the sense of a world-model. However, this ambitious extension will involve further research beyond the scope of this study.

The data analysis system as well as the cartographic output system are, at present, of no concern for this work, and will therefore not be described here.

Connections Between Image Processing And Map Data Processing

The data structures for images and for maps differ because of their acquisition philosophy and the operations intended on them.

Images are stored as matrices and contain at first no explicit information on a structural level, whereas spatial data of maps have the form of vectors associated with location coordinate and can therefore be from the beginning labelled with relational properties. Images are formed "physically" by discretizing a signal which varies over a two-dimensional domain, treating each point uniformly; map data are digitized "logically" by entering meaningful entities such as lines or boundaries from which the objects can easily be reconstructed.

To use map data in image processing and to incorporate scene analysis results to update map information, these structures have to be adapted to one another (Figure 2).

The procedure of vector-to-raster-conversion is well-known and has been used in previous investigations. Single objects can be retrieved from the map data base and transformed to templates or masks. A more involved procedure has to be applied when a whole raster frame must be filled with labels for different regions which together cover the entire area. Most algorithms have difficulties to preserve geometric properties such as area and adjacency under discrete metrics, especially for small objects. Figure 3 indicates the problem by a simple example.

Raster-to-vector-conversion is, for single objects, also relatively easy to handle. However, the errors occuring during processing (discretisation and curve fitting) do not allow conversions to be strictly reversible.

```
                      VECTOR-TO-RASTER-CONVERSION

---------------------                 ----------------------
I                   I   --------->    I                    I
I MAP DATA STRUCTURE I                I IMAGE DATA STRUCTURE I
I     VECTORS       I                 I    IMAGE MATRIX    I
I    RELATIONS      I                 I  RASTER OF PIXELS  I
I                   I   <---------    I                    I
---------------------                 ----------------------

                      RASTER-TO-VECTOR-CONVERSION
```

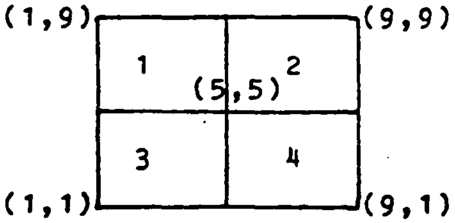
Figure 2: Adaption of map and image data structures

When transforming entire frames to the vector structure an additional problem arises. As the conversion goes from a data structure with low-level implicit relations to high-level explicit relations, these have to be reconstructed. This means that not simply boundaries are of interest, but rather the edges and nodes which separate the different objects. This holds not only for the integration of analysis results into a particular data base, but also if we try to get symbolic descriptions of the image contents.

Approaches To Scene Analysis

Change detection in imagery can be approached in different ways depending on the level of data abstraction.

The most simple process involves only the image domain. Two images have first to be registered with respect to their geometries. Leberl and Ranzinger (1982) have shown that modern instrumentation for navigation can give very accurate ancillary data with which a preliminary registration can be accomplished. A fine overlay with sub-pixel accuracy is possible by subsequent digital correlation. Image differencing then yields indicators for changes. The advantage of this method is mainly its easy implementation. A rough sketch of image contents is thus possible. However, it does not take into account different light conditions and does not yield any clues as to what has actually occured. As a preprocessing step, it may prove nevertheless valuable.



vectors and coordinates

1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
3	3	3	3	4	4	4	4	4
3	3	3	3	4	4	4	4	4
3	3	3	3	4	4	4	4	4
3	3	3	3	4	4	4	4	4

resulting raster

Figure 3: Difficulties in vector-to-raster conversion. Four congruent squares in vector representation do not yield congruent squares in the raster

A complex approach takes place on the symbolic level. Here, the image is first segmented into meaningful parts. These parts are then described in a relational structure which also contains shape and grey value properties. These parts are then matched with the symbolic description of the knowledge-base, in this case with the map contents. In many cases where no detailed spatial knowledge is available, the method proves to be feasible. The segmentation process uses only image-inherent information and will thus be rather complicated. But there exists in our context a comprehensive description of what is to be expected in the image which can be used to guide segmentation.

This leads to a third approach which we are taking in this study: The map data base contains positional as well as relational information to make meaningful segmentation possible. The correspondence between map and image which can first coarsely be established by recognition procedures (developed in previous investigations) is stepwise refined by matching objects of the map data base to image features. The segmentation processes can be made considerably complex without becoming untolerably time-consuming, as the areas in the image domain that qualify for inspection are small. The topological relations represented in the map data base can be exploited to make the search for objects goal-oriented. The spatial description can be exploited to verify recognition by comparing the results obtained to the results expected. Non- verification may point out areas which have undergone changes.

A Strategy

The strategy to be taken relies on the tools provided.

(a) establish geometric correspondence between map and image

(b) select object from data base

(c) transform object to image data structure

(d) select suitable recognition procedure

(e) recognize object

(f) verify match

(g) if verification successful, mark object as present and continue with (b)

(h) if not verified, mark area as unidentified and continue with (b)

This strategy is terminated if the data base is exhausted or a large number of mismatches indicates a severe error. Result is a list with matched/unmatched object and an image which shows the segmentation results. The interpreter now may enter an interaction with the system to resolve identification problems. Updates are optionally entered to the map data base.

Test Data

The aerial imagery selected for test purposes consists of a multitemporal series of four overflights which cover a period from June, 1968 to May, 1982. Scales range from 1:9000 to 1:30000, thus representing different degrees of detail. The imaged area lies south of Graz and was also used in previous studies. There is no significant terrain relief so that problems with geometry should be minimal.

The photos document urban growth with new infrastructure (motorway), industrial settlements and suburban housing. The river Mur serves as an invariant backbone as well as some mayor roads in the area. Agricultural land use and forest are other dominant components. Thus, various tests can be carried out on features with different characteristics.

R E F E R E N C E S

BALLARD D.H, BROWN C.M. (1982): Computer Vision. Prentice-Hall, Englewood Cliffs, N.Y. (USA).

BARROW H.G. u.a. (1977): Experiments in Map-Guided Photo-Interpretation. Proc. 5th Intern. Joint Conference on Artificial Intelligence. MIT, Cambridge, Mass., August 1977.

FISCHLER M., TENENBAUM J., WOLF H. (1979): Detection of Roads and Linear Structures in Digital Images. AI-Laboratory, Stanford, TR 200, Menlo Park, Cal.

HAVENS W., MACKWORTH A. (1983): Representing Knowledge of the Visual World. Computer, 10/83.

KAINZ W., RANZINGER M. (1983): DESBOD - A Geographical Information System. Proc. CAMP 83, Berlin, März 1983.

KESTNER W. (1980): Considerations about Knowledge-Based Image Interpretation. Proc. IAPR, Miami.

KROPATSCH W., LEBERL F.W. (1981): Automated Registration of Scanned Satellite Imagery with a Digital Map Data Base. DIBAG-Publications No. 1, Graz Research Center.

LANTZ K.A., BROWN C.M., BALLARD D.H. (1978): Model-Driven Vision Using Procedure Description: Motivation and Application to Photointerpretation and Medical Diagnosis. Proc. SPIE, Vol. 155, pp.144-157.

LEBERL F., KROPATSCH W. (1980): Experiments with Automatic Feature Analysis Using Maps and Images. Pres. Paper, 14. Kongreß der Internationalen Gesellschaft für Photogrammetrie, Hamburg, BRD, 13. - 24. Juli 1980.

LEBERL F., RANZINGER H. (1982): Registration of Digitized Aerial Photography with a Digital Map Data Base. DIBAG Report No.5, Graz-Research Center.

McCALLA G., CERCONE N. (1983): Approaches to Knowledge Representation. Computer, 10/83.

McKEOWN D., J.L. DENLINGER (1982): Graphical Tools for Interactive Image Interpretation. Computer Graphics, Vol.16, Nr.3, pp.189-198.

McKEOWN D. (1982): Concept Maps. Proc. DARPA IUS Workshop, Stanford, Sept. 1982.

NAU D.S. (1983): Expert Computer Systems. Computer, 2/1983.

RANZINGER H. (1983): Image Processing with an Array Processor. Proc. SPIE, Vol. 397-59.

STIES M., SANYAL B., LEIST K. (1977): Organisation of Object Data for an Image Information System. FIM-Institute, Karlsruhe, FRG.

TENENBAUM M., M. FISCHLER, H. WOLF (1978): A Scene Analysis Approach to Remote Sensing. Technical Note 173, Artificial Intelligence Center, Stanford Research Institute, Menlo Park, Calif.