EXPERIMENTS TO CORRECT A DIGITAL MAP DATA BASE USING SCENE ANALYSIS (II) INSTITUTE FOR IMAGE PROCESSING GRAZ (AUSTRIA)
EXPERIMENTS TO CORRECT A DIGITAL MAP DATA BASE USING SCENE ANALYSIS

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

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**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.
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 scaling 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 Administrative 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
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. Lebej

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A1
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 Cemone (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 database 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 focusing 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 first goal. Thus we have to verify that we can make use of tools 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

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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

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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, simultaneous 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 occurring during processing (discretisation and curve fitting) do not allow conversions to be strictly reversible.

<table>
<thead>
<tr>
<th>VECTOR-TO-RASTER-CONVERSION</th>
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</thead>
<tbody>
<tr>
<td>MAP DATA STRUCTURE</td>
</tr>
<tr>
<td>VECTORS</td>
</tr>
<tr>
<td>RELATIONS</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>IMAGE DATA STRUCTURE</td>
</tr>
<tr>
<td>IMAGE MATRIX</td>
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<tr>
<td>RASTER OF PIXELS</td>
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<td>IMAGE DATA STRUCTURE</td>
</tr>
<tr>
<td>IMAGE MATRIX</td>
</tr>
<tr>
<td>RASTER OF PIXELS</td>
</tr>
</tbody>
</table>

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 occurred. As a preprocessing step, it may prove nevertheless valuable.

![Figure 3: Difficulties in vector-to-raster conversion. Four congruent squares in vector representation do not yield congruent squares in the raster.](image-url)
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 intolerably 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.
REFERENCES


**DIEAG - Instruction Set**

Note: Instruction marked with an asterisk (*) require special hardware devices; instructions marked with a plus (+) sign are computer installation dependent.

### Read/write of Magnetic Tapes with Various Formats

#### Data Reformatting

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CT256</td>
<td>Computed tomography</td>
</tr>
<tr>
<td>DEZDSK</td>
<td>Read list with decimal grey values</td>
</tr>
<tr>
<td>LDSAT</td>
<td>LANDSAT MSS - NASA</td>
</tr>
<tr>
<td>OPTIN</td>
<td>Read Optronics - scanner image data</td>
</tr>
<tr>
<td>OPTOUT</td>
<td>Write image data for output on Optronics filmwriter</td>
</tr>
<tr>
<td>SAR</td>
<td>LANDSAT MSS Telespazio - format</td>
</tr>
<tr>
<td>SARTEST</td>
<td>Ancillary information SAR-580 (airborne radar)</td>
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<tr>
<td>SEASAT</td>
<td>SEASAT JPL - format</td>
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<tr>
<td>TELSAT</td>
<td>LANDSAT MSS Telespazio - format</td>
</tr>
<tr>
<td>TELEHD</td>
<td>Ancillary information LANDSAT - Telespazio - format</td>
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<tr>
<td>TELRBV</td>
<td>LANDSAT RBV Telespazio - format</td>
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### Image Rendition

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDDEZ</td>
<td>Print image grey values as decimal data matrix</td>
</tr>
<tr>
<td>BDGRAY</td>
<td>Image hardcopy on electrostatic plotter</td>
</tr>
<tr>
<td>PLOTFO</td>
<td>Plot contour lines</td>
</tr>
<tr>
<td>PRINT</td>
<td>Print image on lineprinter with 8 grey levels and automatic histogram equalisation</td>
</tr>
</tbody>
</table>

### Image Manipulation

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEOPS</td>
<td>Image pyramid generation</td>
</tr>
<tr>
<td>COPYBD</td>
<td>Copy (sub)image considering optionally given lookup-table and binary mask</td>
</tr>
<tr>
<td>DIRECT</td>
<td>Geometric transformation (magnification, reduction, rotation)</td>
</tr>
<tr>
<td>GRKEIL</td>
<td>Insert grey value reference scale into image</td>
</tr>
<tr>
<td>LADEGR</td>
<td>Create image file with constant pixel value</td>
</tr>
<tr>
<td>NOISE</td>
<td>Impose synthetic noise onto image</td>
</tr>
</tbody>
</table>

### Image Statistics

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENHIS</td>
<td>Generate histogram and store on work-file</td>
</tr>
<tr>
<td>HIST2</td>
<td>Generate two-dimensional histogram and store as image</td>
</tr>
<tr>
<td>LIHIS</td>
<td>Read histogram from image file to work-file</td>
</tr>
<tr>
<td>MINMAXBD</td>
<td>Compute minimum and maximum value in image</td>
</tr>
<tr>
<td>PLOHIS</td>
<td>Plot histogram</td>
</tr>
<tr>
<td>PRIHIS</td>
<td>Print histogram</td>
</tr>
<tr>
<td>SPAHIS</td>
<td>Column histogram of binary image</td>
</tr>
<tr>
<td>STOHIS</td>
<td>Store histogram in image file</td>
</tr>
<tr>
<td>ZEIHIS</td>
<td>Line histogram of binary image</td>
</tr>
</tbody>
</table>
Vector-to-Raster-Conversion

POLBIN rastering of polygon given by vectors, result is binary image, optionally with polygon fill
POLFIT smooth polygons
POLGEN generate polygon file from level contours
POLINF print polygon file information
POLPLO plot polygons

Geometric Rectification

GRIGEN compute deformation description grid from control point data with polynomial warp functions
GRIGAN control print of grid data
PLOKNO control plot of grid data
RESAMP image resampling
CORREL digital image correlation

Digital Terrain Model (GTM) Processing

BGTH convert DIBAG-image to GTM-format
GTMOD convert GTM-format to DIBAG-image
OBERFL generate surface file for perspective view rendition
D3DISP synthetic perspective view of terrain data with different illumination models
optionally generation of distortion information
PQPARA compute local normal vectors
SLOPE compute slope and exposition of surface points
VISEBIN generate mask with visibility information
ILLUIX generate image with synthetic illumination

Interface to DeAnza image display and image array processor

ANZABD read image from display memory and store in DIBAG-Format on disk
ANZLOK read lookup-table from table memory and store in DIBAG-work-file
ANZMAS read binary image from graphics memory and store in DIBAG-work-file
BDANZA display subimage on monitor (8 bit quantisation)
DISPLAY display subimage on monitor (16 bit quantisation)
LOKANZ transfer lookup-table from DIBAG-work-file to table-memory
MASANZ transfer binary image from DIBAG-work-file to graphics memory
D I B G - Instruction Set

Note: Instruction marked with an asterisk (*) require special hardware devices; instructions marked with a plus (+) sign are computer installation dependent.

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Data Reformatting

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LDSAT LANDSAT MSS - NASA
OPTIN read Optronics - scanner image data
OPTOUT write image data for output on Optronics filmwriter
SAR SAR-580 (airborne radar)
SARTEST ancillary information SAR-580
SEASAT SEASAT JPL - format
TELSAT LANDSAT MSS Telespazio - format
TELEHD ancillary information LANDSAT - Telespazio - format
TELRBV LANDSAT RBV Telespazio - format

Image Rendition

BDDEZ print image grey values as decimal data matrix
BDGRAY * image hardcopy on electrostatic plotter
PLOTFO * plot contour lines
PRINT print image on lineprinter with 8 grey levels and automatic histogram equalisation

Image Manipulation

CHEOPS image pyramid generation
COPYBD copy (sub)image considering optionally given lookup-table and binary mask
DIRECT geometric transformation (magnification, reduction, rotation)
GRKEIL insert grey value reference scale into image
LADEBGR create image file with constant pixel value
NOISE impose synthetic noise onto image

Image Statistics

GENHIS generate histogram and store on work-file
HIST2 generate two-dimensional histogram and store as image
LIHIS read histogram from image file to work-file
MINMAXBD compute minimum and maximum value in image
PLOHIS * plot histogram
PRIHIS print histogram
SPAHIIS column histogram of binary image
STOHIS store histogram in image file
ZEIHIS line histogram of binary image
Gray Scale Modification (Lookup-Tables)

**HISLOK**
generate table for equalisation according to given distribution function

**LOK**
manipulate lookup-table

**NEGATE**
invert lookup-table

**SETLOK**
set linear table

**Spatial Filters**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAFABS</td>
<td>Laplace - absolute value sum</td>
</tr>
<tr>
<td>LAPLAC</td>
<td>Laplace</td>
</tr>
<tr>
<td>LAPPOS</td>
<td>Laplace - absolute value</td>
</tr>
<tr>
<td>MASK33</td>
<td>general 3x3 - filter with user-defined weights</td>
</tr>
<tr>
<td>RANKOP</td>
<td>rank operator (e.g. median, minimum, maximum)</td>
</tr>
<tr>
<td>ROBABS</td>
<td>Roberts - absolute value</td>
</tr>
<tr>
<td>ROBERT</td>
<td>Roberts</td>
</tr>
<tr>
<td>ROBMAX</td>
<td>Roberts - maximum</td>
</tr>
<tr>
<td>SMOOTH</td>
<td>averaging</td>
</tr>
<tr>
<td>SOBABS</td>
<td>Sobel - absolute value</td>
</tr>
<tr>
<td>SOBEL</td>
<td>Sobel</td>
</tr>
<tr>
<td>SOBKMAX</td>
<td>Sobel - maximum</td>
</tr>
</tbody>
</table>

**Image Combinations**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADIMAG</td>
<td>linear combination f(G,H) = a.G +/- b.H</td>
</tr>
<tr>
<td>DIST</td>
<td>distance image (values represent distances from mask)</td>
</tr>
<tr>
<td>RATIO</td>
<td>ratio image</td>
</tr>
<tr>
<td>THRESHOLD</td>
<td>image thresholding</td>
</tr>
<tr>
<td>VECLFN</td>
<td>vector length image</td>
</tr>
</tbody>
</table>

**Processing of Binary Images and Masks**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BINAREA</td>
<td>compute area and centre of gravity</td>
</tr>
<tr>
<td>BINCORR</td>
<td>correlate masks</td>
</tr>
<tr>
<td>EIILRU</td>
<td>print mask</td>
</tr>
<tr>
<td>BIXEX</td>
<td>disable processing of mask</td>
</tr>
<tr>
<td>BINFIL</td>
<td>fill interior of area given by mask</td>
</tr>
<tr>
<td>BININ</td>
<td>enable processing of mask</td>
</tr>
<tr>
<td>BINOP</td>
<td>logical combinations of masks</td>
</tr>
<tr>
<td>BINSHI</td>
<td>shift mask within its window</td>
</tr>
<tr>
<td>LIBIN</td>
<td>load mask from image file to work-file</td>
</tr>
<tr>
<td>LIMAS</td>
<td>load mask from mask file to work-file</td>
</tr>
<tr>
<td>MASKBD</td>
<td>set image pixels to constant value at locations defined by mask (choropleth generation)</td>
</tr>
<tr>
<td>NOTBIN</td>
<td>complement of mask</td>
</tr>
<tr>
<td>REGION</td>
<td>region growing</td>
</tr>
<tr>
<td>STOBIN</td>
<td>store mask from work-file on image file</td>
</tr>
<tr>
<td>STOMAS</td>
<td>store mask from work-file to mask file</td>
</tr>
</tbody>
</table>

**Line Following**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PASCOO</td>
<td>interactive input of line transition points</td>
</tr>
<tr>
<td>LINSEA</td>
<td>line following - forward search</td>
</tr>
<tr>
<td>TRACK</td>
<td>line following - backward search</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>ASK</td>
<td>assignment of input/output devices</td>
</tr>
<tr>
<td>BDIINFO</td>
<td>information about existing images</td>
</tr>
<tr>
<td>BKW</td>
<td>definition of actual image name and window for subsequent processing steps</td>
</tr>
<tr>
<td>COM</td>
<td>insert comments into work protocol</td>
</tr>
<tr>
<td>END</td>
<td>end of DIBAG session</td>
</tr>
<tr>
<td>EXIT</td>
<td>pause in DIBAG session</td>
</tr>
<tr>
<td>HELP</td>
<td>information about instruction set</td>
</tr>
<tr>
<td>KILLBD</td>
<td>delete image file</td>
</tr>
<tr>
<td>KILLBIN</td>
<td>delete mask work-file</td>
</tr>
<tr>
<td>KILLHIS</td>
<td>delete histogram work-file</td>
</tr>
<tr>
<td>KILLLOK</td>
<td>delete lookup-table work-file</td>
</tr>
<tr>
<td>KILLWORK</td>
<td>delete all work files</td>
</tr>
<tr>
<td>LOG</td>
<td>print work protocol</td>
</tr>
<tr>
<td>WORK</td>
<td>information about work-file contents</td>
</tr>
</tbody>
</table>
DEANZA TASKS DESCRIPTION on 25-OCT-83

Directory /DEANZA.FZG.EXE

=-=-=-=-=-=-=-= Image Transfer -=-=-=-=-=-=-=-=-=

SAVPIC  save image memories to disc file
SHOPIC  get image from disc file
SHO256  display four different images in 256*2 windows

=-=-=-=-=-=-=-= Image Processing -=-=-=-=-=-=-=-=-=

ADATHR  adaptive thresholding
ARUTIL   perform arithmetic operations on channels
AUTCOR   autocorrelation function via DEANZA
AUTOCR   autocorrelation under a 256x256 (max) cursor rectangle
AVERAG   mean of four images
BASRLP   biased simple edge operator
CONVLV   convolution with cos-exp or own mask
DIDX     simple edge operator
DIFVEC   difference vector image from max.5 images
DIST     mask distance transform
DVP      DVP program interpreter
EDGE     various edge enhancement techniques
LAPLAC   Laplace edge operator
MEDIAN   median approximation under 3x3 mask
MIMAX    minimum and maximum under nxn mask
NDTEST   normal distribution test; CHI square
PCT      principal component transformation - compute
PCT1     principal component transformation - transform
RATIO    ratio image
REGAVG   regional average for texture parameter acquisition
ROBERT   Roberts edge operator
SETPCL   assignment of selected colours to arbitrary pixelvalues
SHOCLA   show pixels with cursor defined values in two images
SOBEL    Sobel edge operator
THRESH   interactive threshold determination
VECLEN   create vector length image

=-=-=-=-=-=-=-= Binary Image Processing -=-=-=-=-=-=-=-=-=

BINRNK   rank operator on binary image
BLOSHR   blow/shrink rank operator
MASKCL   clean binary mask
MASKOP   set/clear pixels in binary mask according to neighbors
MASKWD   calculate DIBAG window of binary mask
PCTBIN   PC-trafo for masks
SHOBIT   show binary image transformation table
SKELET   skeletonisation

=-=-=-=-=-=-=-= Memory Manipulation -=-=-=-=-=-=-=-=-=

CLRMEM   clear memory
CPYMEM   copy memories
FLICKR   exchange two image channels
FLIP     mirror or rotate image channel
SPLIT    copy half image
------------------------ Image Enhancement ------------------------

ENHANCIAE image enhancement via LUT; lin.ramp from 0.1-99.9%
ENHANCE image enhancement via LUT; lin.ramp from 1-99%
EQUIL Automatic linear ramp generation
HILITE blinking threshold region
IHSRGB intensity-saturation-hue to RGB
IHSRGBHR intensity-saturation-hue to RGB; high resolution
IP5MCC contour lines
IP5UNI histogram equalisation
JP5ITIT manipulate lookup-tables with joystick
MAHITIT special functions for rendition on screen
PLOTIT plot ITTs in G/O
PSEUDO interactive pseudo colouring module
REDRES change image resolution
SETITT manipulate ITTs or LUTs
SFG set SFG parameters
SPLICU manipulate splitscreen coordinates with joystick
WIND16 manipulate ITTs for 16 bit image data

------------------------ Histograms and Statistics ------------------------

HISTO calculate print and plot a histogram
HIST2 two dimensional histogram
LINHIS generate line histograms
PIXVAL interactive pixel value determination
ROBUST robust statistic estimates from image
SNSHIS separate histograms for each Landsat sensor
THRLLI calculate limit under which p percent of pixels lie

------------------------ Zoom and Scroll ------------------------

INTPZM zoom with software interpolation
JSCRZM scroll and zoom image
JSCZM zoom image
LDSCR scroll three images simultaneously in SFG windows
SMALL reduce 512x512 image to 256x256 in upper left quarter

------------------------ Graphic Overlay ------------------------

PLTIMAP superpose map (vector) data
REGDEF define region with joystick and vector fill
SETIT4 manipulate ITT for graphic overlay
SETOV set pixels in G/O with joystick
TICKS plot tick grid or various marks

------------------------ Image Annotation ------------------------

EDITAN edit annotation overlay
IP5AIN write annotation
SHOWAN get annotation from disc file
SHOWPG load the A/O from a text file
SAVEAN save annotation to disc file
ANZDEZ: print image window values defined by cursors
BXLOOP: loop through black/white rendition of channels
GENPIC: generate .PIC file with 0-values
IMLOOP: show animated 'film'
SELCP: select control points
SKALA: show scale marks on reference scales
WRSCAL: write reference scale to image file or channel

ANACLA: analyze classification statistics; print value ranges of gray values for each image
ANAHIS: analyze histogram to show multiple classifications
BILANZ: count classified pixels in selected raster
BILGRA: result of BILANZ as image
CLADIS: compute class.distsances per image on .STA file
CLUSTA: cov.matrix, inverse and determinants; corr-matrix; eigenvectors of the cov-mat for a set of train-pixels
CMPCLA: comparison of classification results
JNIST: distances of clusters
MAXCLA: reclassify image according to most frequent class in the neighbourhood of each pixel
MAXLIK: maximum likelihood classification
MINDIS: minimum distance classification
PADEPI: parallel epiped classification
PIXLST: list of pixel coordinates which are marked in G/O
PIXSTA: compile statistics for training areas
PLTFEA: plot of feature vectors
PLTHAP: draw situation over img
PIXVST: get feature values for pixels in training areas
RECLAST: reclassify multiply classified pixels
SCATTER: scatter plot of training pixels
SHOCLU: interactive classification
TESTID: a priori test minimum distance classification
TESTML: a priori test max.likelihood classification
TESTP: a priori test parallel epiped classification

ANZBIM: output of binary mask of G/O to VERSATEC or .BIN file
ANZCOL: output of image with gray scale software to VERSATEC
ANZCOLG: output of image with gray scale software to .BIN file
BINOUTPRI: generate plotfile for PRISM dot matrix printer

CHVRGE: test image
COLTAB: color table for color selection
DEMOB: demonstrate rectangle generation
DEMCUR: demonstrate cursors
POLYDG: demonstrate vector plotting
QUADER: create test image (ascending ramps in two channels)
SELCOL: route memories via SFG to video
SHOWLY: checkerboard pattern in channel
SHSPLT: SFG-splitscreen capability demonstration
SPINCC: mirror all channels on vertical centerline
SPIRESC: scroll image channel in spirals
SPTM: generate linear ramps in memories
TESTIM: test image
TESTP: generate a test pattern
### Development Tools

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVPTST</td>
<td>define an instruction for the DVP</td>
</tr>
<tr>
<td>DVPREG</td>
<td>run the DVP with octal register input</td>
</tr>
</tbody>
</table>

### Management

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREIP5</td>
<td>connect VAX to DEANZA</td>
</tr>
<tr>
<td>DELIP5</td>
<td>disconnect VAX from DEANZA</td>
</tr>
<tr>
<td>DEADMP</td>
<td>dump of DeAnza registers octal</td>
</tr>
<tr>
<td>STATUS</td>
<td>show status of deAnza environment</td>
</tr>
<tr>
<td>SWITCH</td>
<td>switchboard utility</td>
</tr>
<tr>
<td>SYSINT</td>
<td>system initialisation</td>
</tr>
</tbody>
</table>
CODES FOR FUNCTIONS IMPLEMENTED IN THE DVP OPERATIONS PROGRAM DVP

DVPCLR  1  DVPCPY  2  DVPSAT  3  DVPCPL  4
DVPSSHF  5  DVPSHB  6  DVPSCH  7
DVPADD  11  DVPSUB  12  DVPHUL  13  DVPDIV  14
DVPMAX  15  DVPKIN  16  DVPCNT  17  DVPSUM  18
DVPAL  19  DVPSQR  20
DVPADC  21  DVPSBC  22  DVPHLC  23  DVPDVC  24
DVPINC  25  DVPDEC  26  DVPAVG  27  DVPLIN  28
DVPADDL  29  DVPTHR  30
STORCH  31  LOADCH  32  SETRMC  33  SCROLL  34
PIXCHK  35  SETCUR  36  NBMAP  37  NLCNT  38
ZOOM  39  SCRLZM  40
DVPMAR  41  DVPCLT  42  DVPMCY  43  DVPMEC  44
DVPMID  45  DVPMOR  46  DVPMEO  47  DVPMEQ  48
DVPCMP  49  DVPCME  50
DVPAIS  51  DVPLOC  52  DVPEXP  53  DVPEEU  54

TO SOFTWARE SWITCHBOARD ... 99

INPUTS REQUIRED

GENERAL PROCEDURE: FIRST PROMPT IS FOR OP-CODE
SECOND PROMPT IS FOR PARAMETERS
2 IS END

RWC MEANS REGIONAL WRITE CONTROL CODE
0 - UNCONDITIONAL
1 - REGION DEFINED BY CURSORS
2 - REGION DEFINED BY CURSORS AND
   RWC BIT OF ITI4
3 - REGION DEFINED BY CURSORS AND
   COMPLEMENT OF RWC BIT OF ITI4
OP-CODE

DVFCCLR (1) clear image memory
DVFCPY (2) copy image memory
DVFSSET (3) set memory to value
DVFCPL (4) copy image memory via lookup-table
DVFSHF (5) shift 16 bit
DVFSHB (6) shift 8 bit
DVFXCH (7) exchange two images in memory
DVFADD (11) addition 8+8 bit
DVFSUB (12) subtraction 8-8 bit
DVFMUL (13) multiply 8 times 8 bit giving 16 bit result
DVFDIV (14) divide 8 into 8 bit giving 8 bit remainder
DVFMAX (15) maximum of two channels
DVFIN (16) minimum of two channels
DVFCT (17) get count register contents
DVFSUM (18) sum over all pixels
DVPA16 (19) addition 15+8 bit
DVPSQR (20) square root of 16 bit
DVFAD (21) addition of 8 bit constant
DVFSBC (22) subtraction of 8 bit constant
DVFMALC (23) multiply by 8 bit constant
DVPVC (24) divide by 8 bit constant
DVPINC (25) increment image memory
DVPDEC (26) decrement image memory
DVPAVG (27) mean of two images
DVPLIN (28) scaled linear combination of images
DVPADL (29) addition 8 bit modified by ITT + 8 bit
DVPTH (30) threshold on image
STORCH (31) save memory to disc file
LOADCH (32) load memory from disc file
SETKMC (33) set regional write control bits in ITT4
SCROLL (34) set scroll for DVP in DIBAG coordinates
PIXCHK (35) check pixel values in memories
SETCUR (36) allows manipulation of cursors to fix window
NBMAP (37) map neighbourhood in binary mask to 8 bit number
NBCNT (38) count pixel neighbourhood
ZOOM (39) zoom
SCRLZM (40) scroll and zoom of specified channels
DVPHAR (41) area of mask
DVPCLB (42) clear bit plane
DVPHCY (43) copy mask (bit plane)
DVPHCP (44) complement mask
DVPHND (45) .and. masks
DVPHOR (46) .or. masks
DVPEEQ (47) exclusive .or. masks
DVPM (48) equivalence masks
DVPMCHP (49) set flag mask after comparing two images =
DVPMCH (50) set flag mask after comparing two images =
DVPA (51) absolute value of 7 bit signed number
DVPL (52) log function on image
DVPEX (53) exp function on image
DVPSOO (54) boolean operations on images