THE AUTOMATIC DISCOR-SYSTEM FOR RECTIFICATION OF SPACE-BORNE IMAGERY AS A BASIS FOR MAP PRODUCTION

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ABSTRACT

Due to their improved radiometric and geometric resolution the new generation of space-borne imagery (e.g. Landsat-4, SPOT, MOMS,Metric Camera) will become more and more important for map production and revision. For this purpose the multisensoral images have to be rectified on a common geometric basis. This basis can be an existing map or a rectified reference image (e.g. orthophoto). The paper describes the Digital Software Correlator for Image Rectification DISCOR. The system allows picture preprocessing, choice of different correlation and rectification functions, threshold correlation, variable window size, iterative and subimage rectification. The process can be controlled by user interaction or automatic procedures.
The paper presents status and possibilities of the DISCOR-system and gives some examples of multisensor image production (e.g. LANDSAT-SEASAT-frame camera).

Introduction

Due to their high information content, remote sensing imagery of the Earth's surface has become more and more indispensable for research in various geoscientific disciplines. For a long time photogrammetry has been using conventional aerial photography taken from aircraft. In recent years, new satellite-borne remote sensing systems and sensors have improved the work and enlarged the possibilities of photogrammetry.

On the other hand, hard- and software tools for the appropriate evaluation of the multitemporal, multisensoral, multispectral and multispatial data have to be developed. The new systems with improved radiometric and geometric resolution will raise the problems of multi-image processing. Ground data, either in analog form or stored in data files have to be linked to the remote sensing image processing systems.

Due to the increasing flood of data systems for combined evluation of remote sensing images and digital ground data have to work as automatically as possible. One part of such a system is the geometric restitution of multi-source remote sensing imagery to desired scale as basis for map production and revision. For this purpose the multisensoral images have to be rectified on a common geometric basis. This basis can be an existing map or a rectified reference image (e.g. orthophoto). Automatic control can be achieved by applying correlation techniques. For this purpose at the Institute of Photogrammetry of the University of Hannover the digital software correlator DISCOR for relative image rectification has been developed. In the following, the requirements, design and realization as well as some results of the DISCOR system will be described.

Mapping possibilities from space

In present times every country in the world has an increasing demand for maps in quantity and quality to satisfy the different requirements of society such as:

- survey and management of natural resources
- environmental monitoring and planning
- geo-referenced data concerning the human activities.

The current status of world mapping, especially in developing countries, leaves much to be desired [KONECNY et al. 1982]. Up to now map production and revision is carried out mostly by two conventional methods:

- terrestrial survey
- aircraft photogrammetry.

Due to the relatively high costs and slow speed the demand of map revision and production at a scale of 1:50 000 - 1:200 000 cannot be fulfilled with these conventional techniques [KONECNY et al. 1982].
In order to meet the mapping needs it will therefore be necessary to explore remote sensing possibilities from space. The cartographic potential of the first generation of satellites is limited to large scale mapping due to their limited spatial resolution [WONG 1975, KELLER 1976, WELCH and PANNELL 1982]. According to their better geometric resolution the new generation of space-borne imagery fulfills cartographic requirements for medium scale mapping [CHEVREL et al. 1981, WELCH and MARKO 1981, KONECNY et al. 1982, COLVOCORESSES 1982, WELCH 1983]. Table 1 summarizes the expectations of today and future space missions.

Table 1: Expected cartographic suitability

space mission	flight altitude/ km	ground pixel/m	resolution in lp/mm	detail detectability/m	expected cartographic suitability
LANDSAT-4 (TM)	705	30			1:600 000
Spacelab Metric Camera Atlas A	250		40	20	1:100 000
Spacelab Metric Camera Atlas B & C	250		80	10	1: 50 000
Large Format Camera/NASA	300		40-70	25-14	1:100 000
SPOT (Pushbroom-Scanner)					
- panchromatic	1000	10			1:150 000
- multispectral	1000	20			1:300 000
MAPSAT					
- panchrom.	1120	10			1:150 000
- multispectral	1120	30			1:450 000
STEREOSAT	705	15			1: 250 000
Stereo-MOMS	480	8			1:100 000

The new space-borne imagery offers a powerful tool for topographic and thematic mapping at moderate prizes [KONECNY 1982]. Except for the camera missions all sensors will record and forward digital data, so that effective evaluation should be executed digitally.

Geographic Information Systems

On the other hand,data obtained from remote sensing systems can be put to their best use if they are incorporated in a system capable of efficient data storage and expedient data processing and retrieval, in so-called Geographic or Geo-based Information Systems [GIS]. A GIS is designed to accept large volumes of spatial data, derived from a variety of sources, including remote sensors, and to efficiently store, retrieve, manipulate, analyze and display these data according to user-defined specifications [MARBLE and PEUQUET 1983]. Remote sensing provides one source of data for such systems, and has the potential to improve the quality and quantity of data available. But the main data source up to now has been the analog map, and the input phase of the GIS is the creation of digital files from map documents. But the GIS offer an effective tool for map revision and map production making use of space-borne imagery as input data source [MITCHELL 1977, MIILAZZO 1980]. Fig.1 shows an example of a GIS data base.

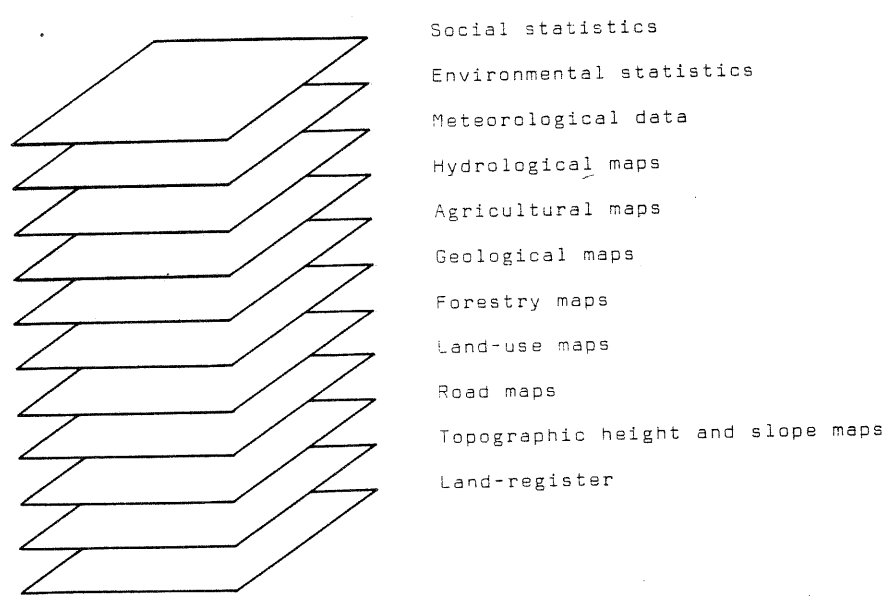

Fig.1: GIS data base

After converting into the desired GIS spatial format remote sensing imagery can serve as input for thematic or topographic map revision or - in developing countries - as source for a new GIS to be created [GÖPFERT 1982, GIALDINI 1983, GARVEY 1983]. Fig.2 represents the data flow inside a GIS.

But how can the multi-source and multi-sensor data be connected for common evaluation? One important step hereby is the geometric restitution of remote sensing imagery according to the GIS scale. One main aim of developping rectification systems is to replace human interaction by automatic components. If a reference image exists, the rectification of other remote sensing images should be executed mainly automatically. Reference images can consists of digital GIS maps or other rectified remote sensing imagery [e.g. digital orthophotos].

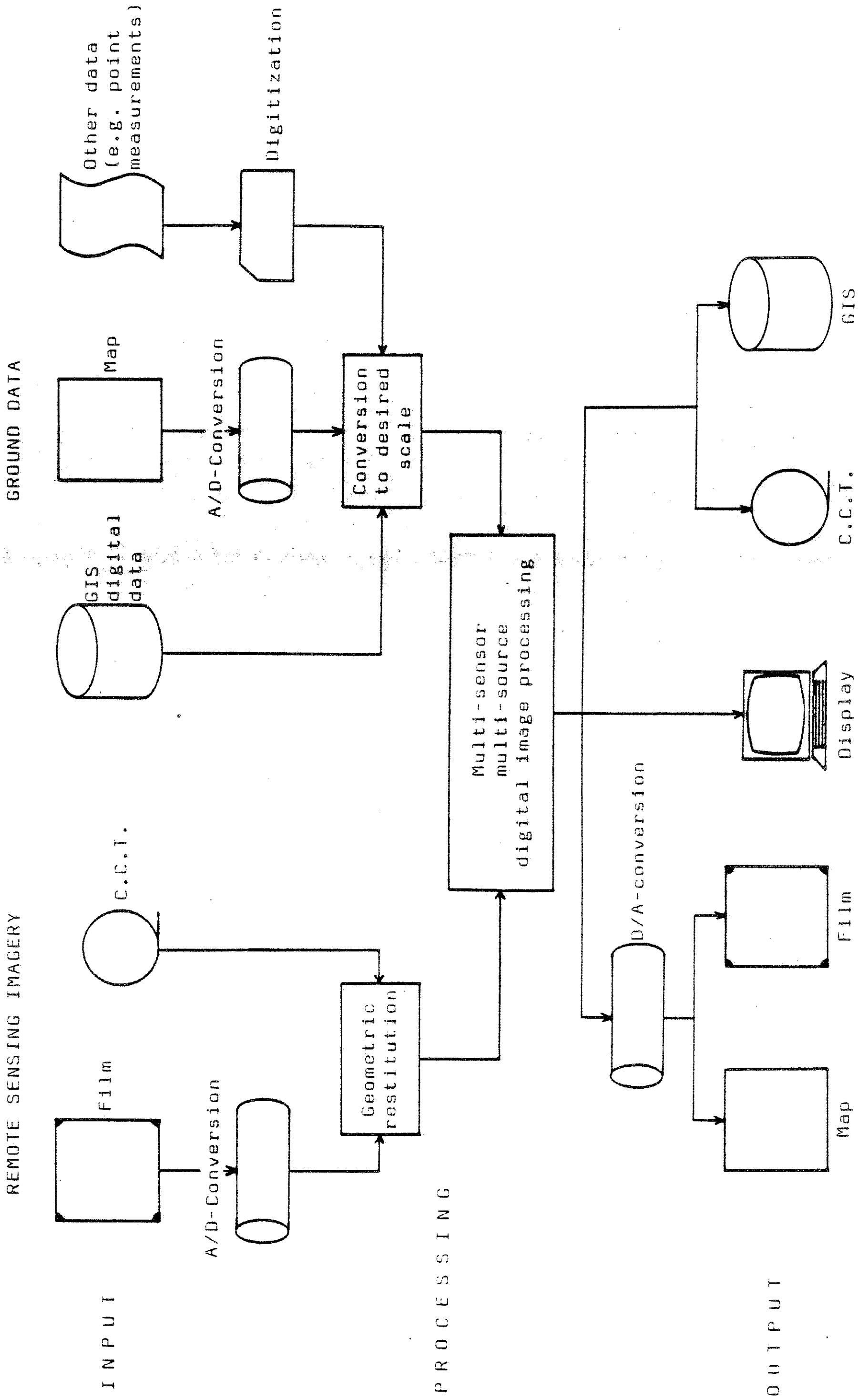

Fig.2: GIS data flow

Automatic rectification system

Picture rectification requires the knowledge of identical points in different images of the same area. The geometric transformation between these 'control points' allows the estimation of final rectification parameters according to the applied mathematical model (KONECNY 1976). Therefore an automatic rectification system must consist mainly of five components (EHLERS 1983):

- Digitization
- Automatic extraction of control points in the reference image
- Automatic identification of the control points (= correlation) in the image to be rectified ('search image')
- Rectification
- Multi-image evaluation.

All these components are related to each other. The accuracy of point identification for instance determines directly the rectification quality, i.e. the rectification method cannot achieve higher accuracy than the underlying control point identification. On the other hand, it is not necessary to apply functions for control point identification that are more accurate than the desired rectification algorithm (indirect dependence). Fig.3 tries to describe the nonlinear 'dependency network' of the system components.

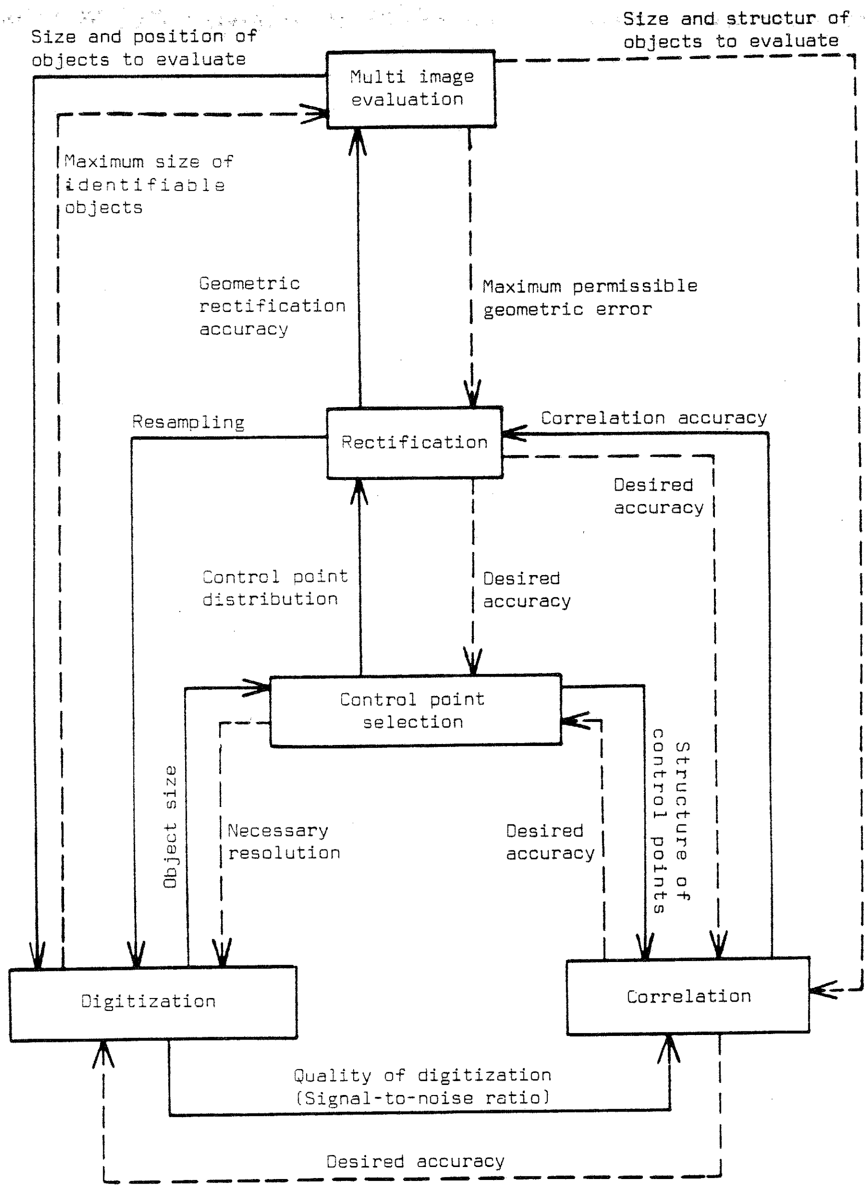

Fig.3: Direct and indirect relations of system components

The solid lines stand for direct, the dashed ones for indirect relations. The term 'correlation' is used for control point identification.
In praxis, such a nonlinear and academic system must be simplified and linearized before being put into reality.
The evaluation target, e.g. multisensoral classification, must be the basis for the automatic control of the rectification system. It determines the sampling rate at the A/D conversion process and controls the correlation and rectification algorithms. Other control parameters are associated with the applied sensor and platform, image size and terrain. Interior parameters include image quality and texture and accuracy of the correlation and rectification functions. The diagram in Fig.4 outlines the linearized automatic correlation and rectification concept.

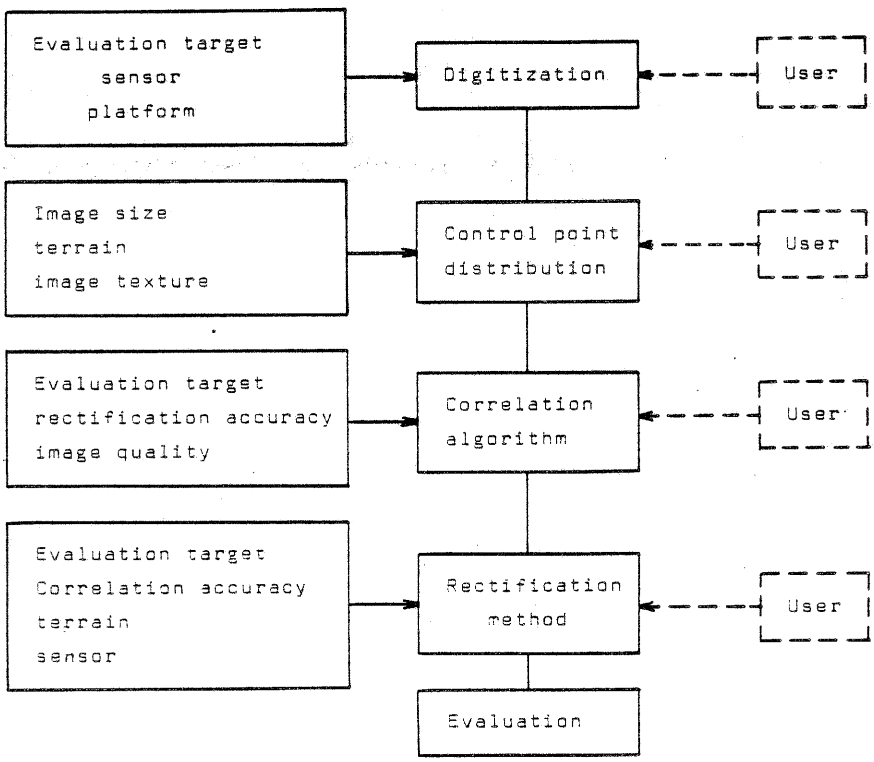

Fig.4. Automatic rectification system

The performance of the system components is controlled by the exterior and interior parameters. User interaction is possible at each level and is plotted in dashed lines. In praxis, the realization of such an 'ideal' system must consider the existing hard- and software environment as well as the capacities in time, money and manpower.

The DISCOR-System

The correlation-rectification system of Hannover University was to be integrated into the digital interactive image processing system MOBI-DIVAH (DENNERT-MÖLLER et al. 1982). So, the interactive component of this system replaces the automatic control wherever it is suitable and reasonable. Fig.5 shows the semi-automatic system of MOBI-DIVAH. User interaction dominates the components **digitization** and **rectification.** The remaining automatic components **control point distribution** and **correlation** can be controlled by image quality and texture (and, of course, by the evaluation target).

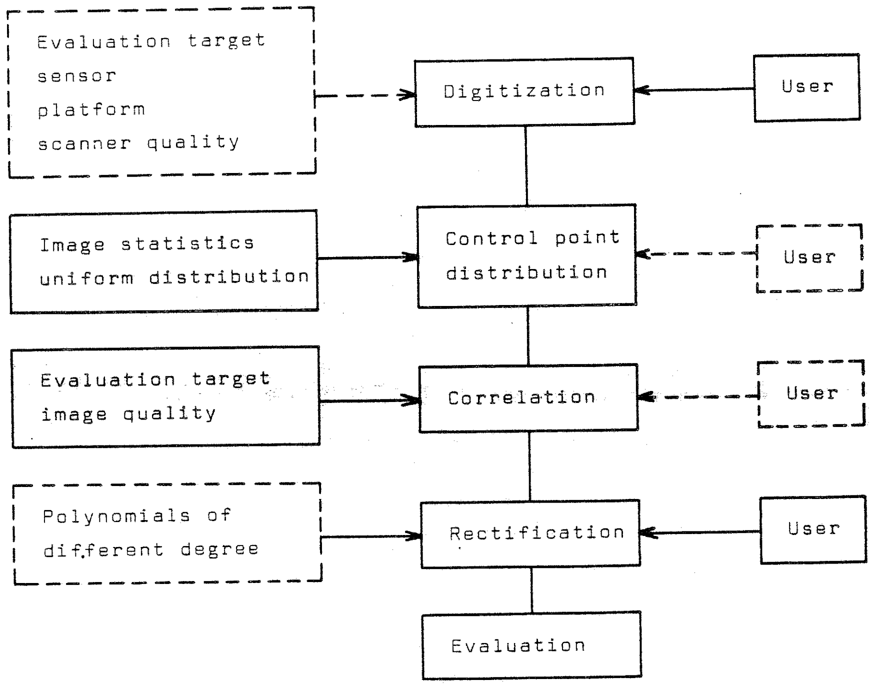

Fig.5: Semi-automatic rectification system

Control points with a high identification probability can be detected by statistical methods. Correlation windows with high variances (= high SNR) have greater correlation probability than those of low variances (EHLERS 1983). Other point finding methods, proposed for instance by MORAVEC, 1980 or DRESCHLER und NAGEL, 1982 can be applied as well. Human eye controlled determination can be performed on the digital DIVAH screen. Correlation methods can be automatically selected by SNR computation. Five different objective functions for the correlation process with different probabilities and computation times are available (EHLERS 1983):

- The 'normal' product moment correlation coefficient.
- The correlation intensity coefficient that has been derived from coherent-optical considerations. The image signals are mapped on the complex plane and the intensity of the complex correlation function is computet. The coefficient is weighted by the local variances around the control points.
- The correlation intensity coefficient (like 2) weighted by the global image variances.
- The Laplace coefficient, i.e. the summarized absolute differences of the image signals.
- The phase correlation coefficient, i.e. the inverse Fourier transform of the normalized cross spectrum of the image signals.

Empirical-statistical tests show great differences in correlation probability and computation speed (EHLERS 1982).
The diagram in Fig.6 demonstrates the DISCOR system for image rectification.
DISCOR allows geometric and densitometric picture pre-processing, variable window size, iterative and subimage rectification.

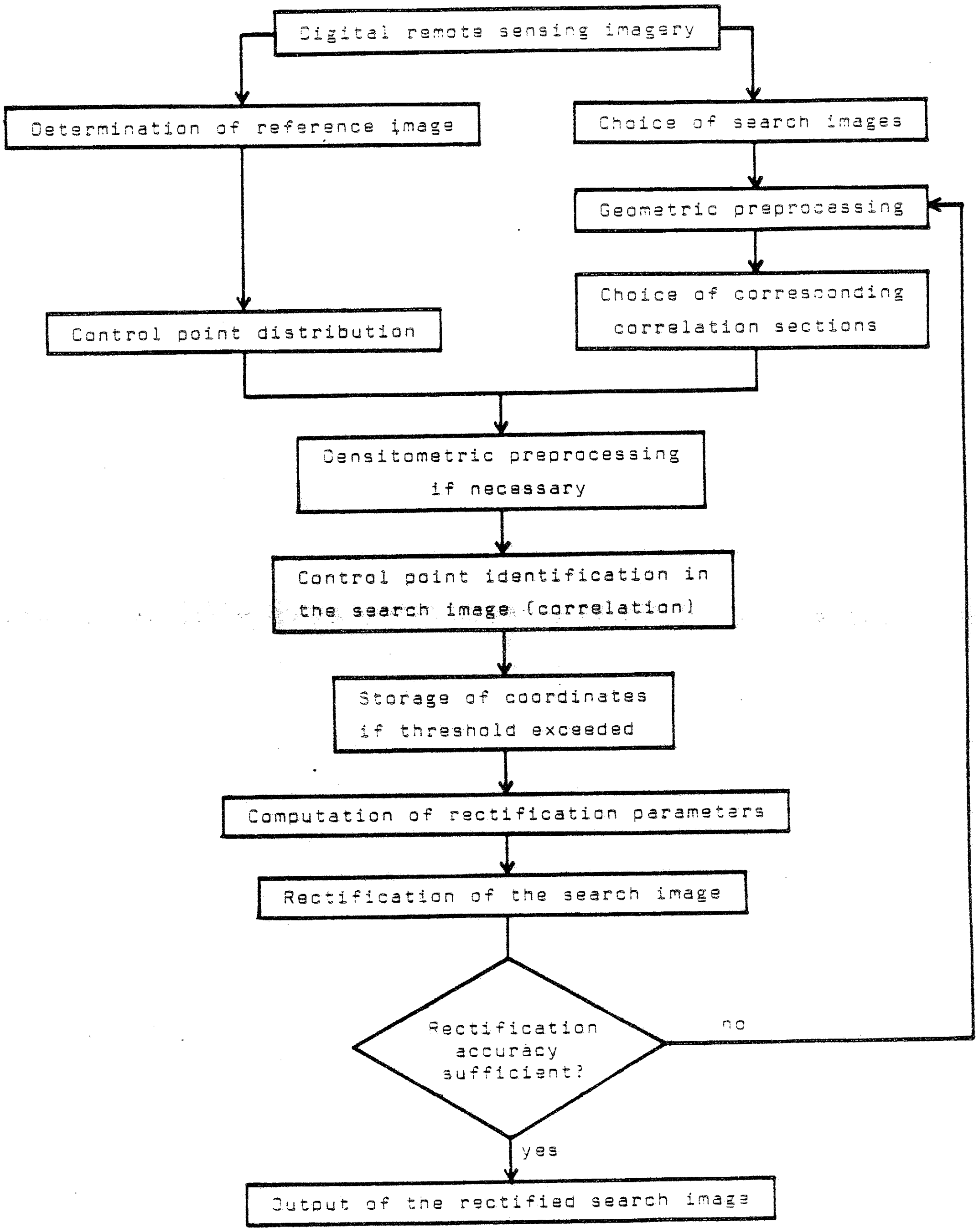

Fig.6: DISCOR performance

The performance of DISCOR is presented in the following chapter with some examples of multisensor image rectification.

DISCOR results

Aerial photograph - LANDSAT overlay

Fig.7 shows a LANDSAT MSS image of the North Fresian coast and according tidal lands from April 1976. This LANDSAT image shall be overlayed an aerial wide-angled photograph from October 1979 taken by a Zeiss frame camera (RMK) showing part of the same region (flying altitude 11 km).

Fig.8 presents the analog preprocessed and digitized RMK-reference image. The digital preprocessed LANDSAT subimage is shown in fig.9. 74 control points for correlation and rectification are measured on the screen of the MOBI-DIVAH image processing system. Fig.10 shows their distribution.

Fig.7: LANDSAT MSS image

Fig.8: Frame camera reference image

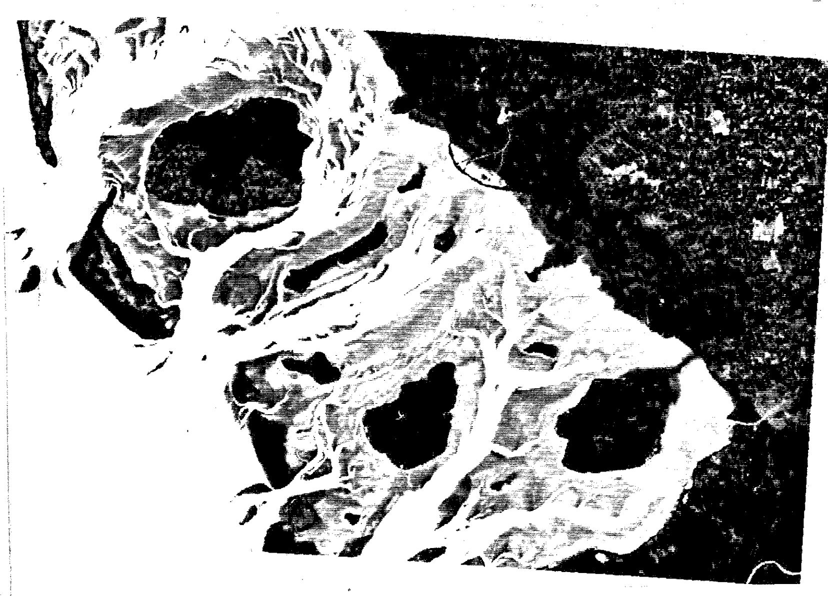

Fig.9: LANDSAT search subimage

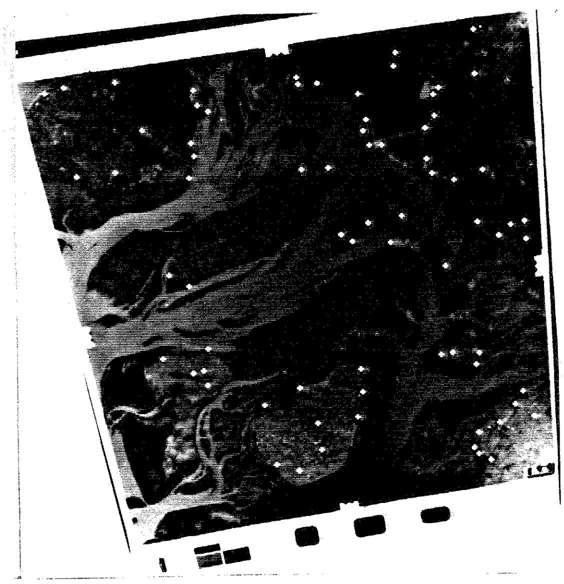

Fig.10: Control point distribution

Table 2 gives the results of correlation and rectification. For correlation the normal correlation coefficient has been chosen, polynomials of 2nd degree serve as rectification functions. The first line of table 2 contains the result of rectification without correlation (control points in the LANDSAT image are also measured on the COMTAL system).

Improvement of rectification accuracy can be achieved by correlation and rectification especially with an iterative procedure.
Fig.11 shows the final rectification of the LANDSAT search image.

Table 2: Correlation and rectification results

Mean correlation maximum R_{max}	Residues in x-direction in pixel	Residues in y-direction in pixel	Threshold for R_{max}	Number of rejected control points	Rectification procedure
-	7.6	4.2	-	-	without correlation
0.51	2.9	3.6	0.35	12	1 x correlation and rectification
0.56	2.7	3.1	0.35	9	2 x correlation and rectification
0.58	2.5	2.9	0.35	9	2 x correlation, subpixel interpolation and rectification

Fig.11: Rectified LANDSAT subimage

LANDSAT-SEASAT Overlay

Launched June 26, 1978, SEASAT-1 was the first of a proposed series of oceanographic research satellites. Among its 5 sensors it contained a L-band synthetic-aperture imaging radar (SAR). Fig.12 shows a SEASAT-SAR image of the city of Cologne (F.R.G.) which should be rectified on a LANDSAT-MSS image of the same area (fig.13).

Fig.12: SEASAT-SAR image

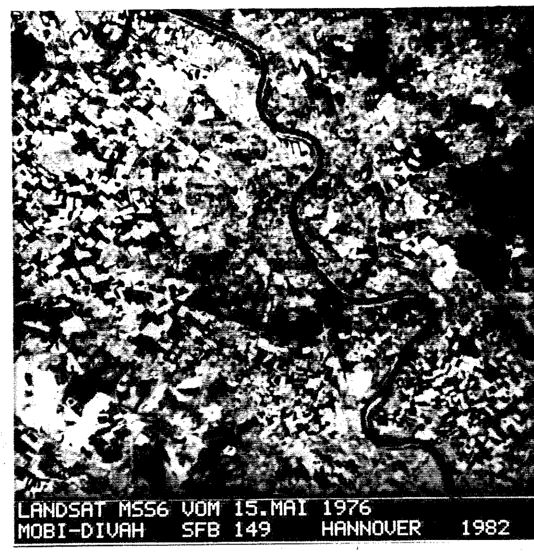

Fig.13: LANDSAT-MSS reference image

Due to the different recording geometries the rectification was performed in subimages which were merged together after rectification. Image partitioning and 80 control points for correlation and rectification are shown in fig.14, results of subimage correlation and rectification in table 3.

Table 3: Correlation and rectification results

Mean correlation maximum R_{max}	Residues x-direction in pixel	Residues y-direction in pixel	Threshold for R_{max}	Number of rejected control points	Degree of rectification polynomials	Rectification procedure
0.20	15.9	18.1	- 1.0	-	1	prerectification
0.20	12.3	14.9	- 1.0	-	2	
0.41	5.6	4.9	0.2	2	1	final rectification
0.40	4.3	4.6	0.2	2	2	

The rectification procedure was performed in two steps. First, the correlation was executed with small pattern matrices (9 x 9 pixel) to achieve approximate control points for pre-rectification (zero-order-solution). The second correlation was done with pattern matrices of larger size (15 x 15 pixel) and a correlation threshold of 0.2 to estimate the control point coordinates for final rectification. To avoid strong extrapolation effects at the subimage edges, the final rectification was executed with polynomials of first degree. The result can be seen in fig.15.

Fig.14: Image partitioning and control point distribution

Fig.15: Rectified SEASAT puzzle

Conclusions

With the DISCOR-system multisensoral and -temporal remote sensing imagery can be combined to one image for further mutual evaluation. Examples of LANDSAT-MSS, frame camera and SEASAT-SAR show the present possibilities of the system. All existing and future image processing functions of the MOBI-DIVAH system can easily be integrated. Thus DISCOR fulfills the needs of flexibility and extension possibility. So space-borne imagery from future satellites like MAPSAT and STEREOSAT as well as images from camera experiments (ATLAS and LFC) can be included.

Next DISCOR experiences shall be performed with **Metric Camera** photography from SPACELAB and **LANDSAT-4 TM** data (if available). Digitized maps shall serve as reference images. For this, methods for contour and feature extractions in the remote sensing imagery prior to correlation must be developed and applied (see HUANG 1981). In addition, terrain models must be considered in the rectification procedures.

Due to its software nature, future features and extensions can easily be integrated into the DISCOR system, so that it will be able to operate also with space-borne imagery from tomorrow.

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