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GEOMETRIC RECTIFICATION OF BLOCKS OF MULTISPECTRAL SCANNER IMAGES

SUMMARY

Geometric distorsions of MSS images are determined and described by applying an interpolation function (nonparametric solution via least squares interpolation). This is made possible by involving data on control points (identical points of the MSS image and of the rectification base (=map, orthophoto)). The solution can be improved by adding data on tie points (identical points of two adjacent MSS strips) so to assure a possible good continuity of the rectified image. The rectification itself can be performed either digitally (re-arranging image pixels in a general purpose computer, input=magtape, output=magtape) or optically (differential image transformation with the orthophoto instrument Avioplan OR1, input=film, output=film). The block is created in the process of re-arranging pixels in the digital case, and by manual mosaicing of the individual rectified images in the optical case. The capability of dividing the block into sub-blocks enables the handling of large quantities of data.

1. INTRODUCTION

Unlike the geometry of photographs taken with photogrammetric cameras which can be approximated well enough as a central projection, the geometry of scanner images is hard to express mathematically. Any distrubance in the flight during scanning influences the correponding image details. As a result, the distortion of MSS images is a function not only of coordinates of location but of time, as well. The geometric rectification of these images is, however, inevitable in solving certain tasks of compilation. It is enough to think of compilation of multitemporal recordings, of image classification with object space characteristics, and of prescribing object space coordinates to image details.

2. SOFTWARE DEVELOPMENT, AND NECESSARY INSTRUMENTS

The Institute of Photogrammetry of the Technical University of Vienna deals since some years with the rectification of photogrammetric and MSS images by applying the universal digitally controlled orthophoto projector Avioplan OR1 of the Wild Company. In a cooperation with the firm Austroplan (Spacetec) a computer program has been developed for the purposes of digital image rectification. This program fulfilles the special requirements as determined by the instruments developed by Spacetec. The instrument GOBI developed by Spacetec is capable of producing color prints of digital images up to the format 80 x 120 cm. Such large format fits ideally the purpose of handling blocks of strips of MSS images, so to mosaic them together as if they were a single large MSS image. Through additions and changes it was then possible to apply this program for the optical rectification of MSS images in the Avioplan OR1. In this case a simultaneous output of blocks of images is not possible. Past the optical process individual rectified images can be fitted together without discrepancies (an example: the Satellite Photomap of Austria).

3. RECTIFICATION METHODS

There are two essentially different ways of geometric rectification. The first one is the so called parametric solution. It tries to determine projection equations changing scanwise, with parameters describing the real circumstances causing the geometric distortions. With these equations, the rectification can then be performed. The circumstances mentioned can be such as fluctuations in speed and height of the aeroplane, changes in leanings of the camera platform, terrain height differences, and perspective panoramic effects. Furthermore, the choice of a cartographic projection for the rectified image exercises important influences, especially in the case of small scale images, such as taken from satellites.

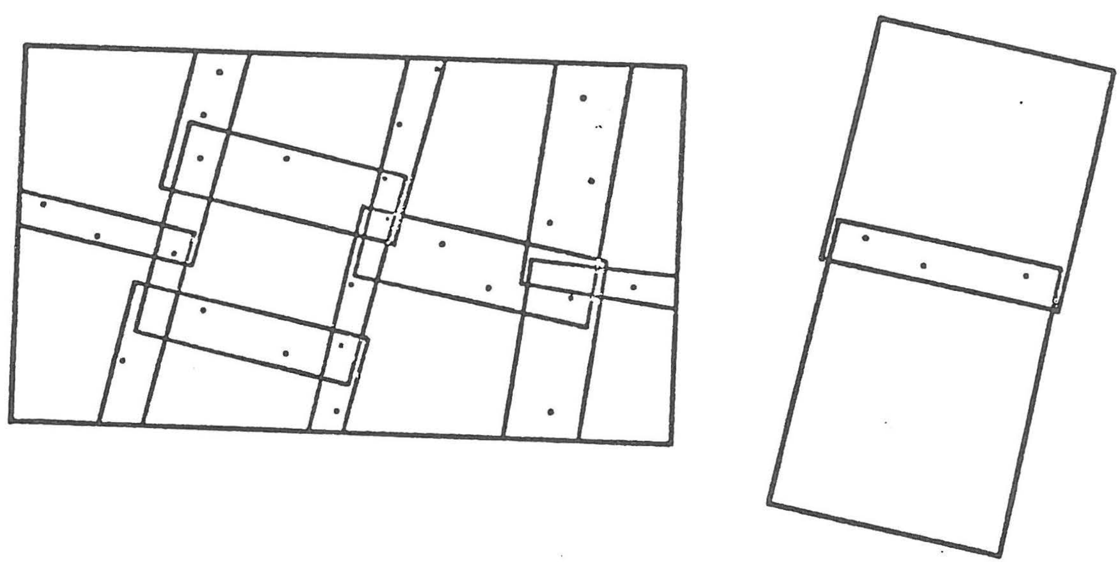
The second way of geometric rectification, the nonparametric one, is not concerned with the causes of distortion. It rather tries to deal with them by approximating image distortions as found in control points applying some interpolation method. Control points are identifiable common points of some geometrically correct basis and of the image to be rectified. Geometric distortions in these control points make it possible, to interpolate the vectors of correction for any intermediate point. This procedure can be combined with some simple parametric solution. So, it is readily possible and advantageous to predetermine parameters of e.g. the perspective distortion and the scaling factor, and to interpolate then only the remaining residuals.

4. THE CONCEPT AND MATHEMATICAL BASIS OF BLOCK FORMATION

At this point, the nonparametric way of image rectification is applied. As interpolation method the least squares interpolation (QUINT) is used. The role of rectification base, determining the geometry of the rectified image, is usually played by graphical maps, and in some cases by orthophotos.

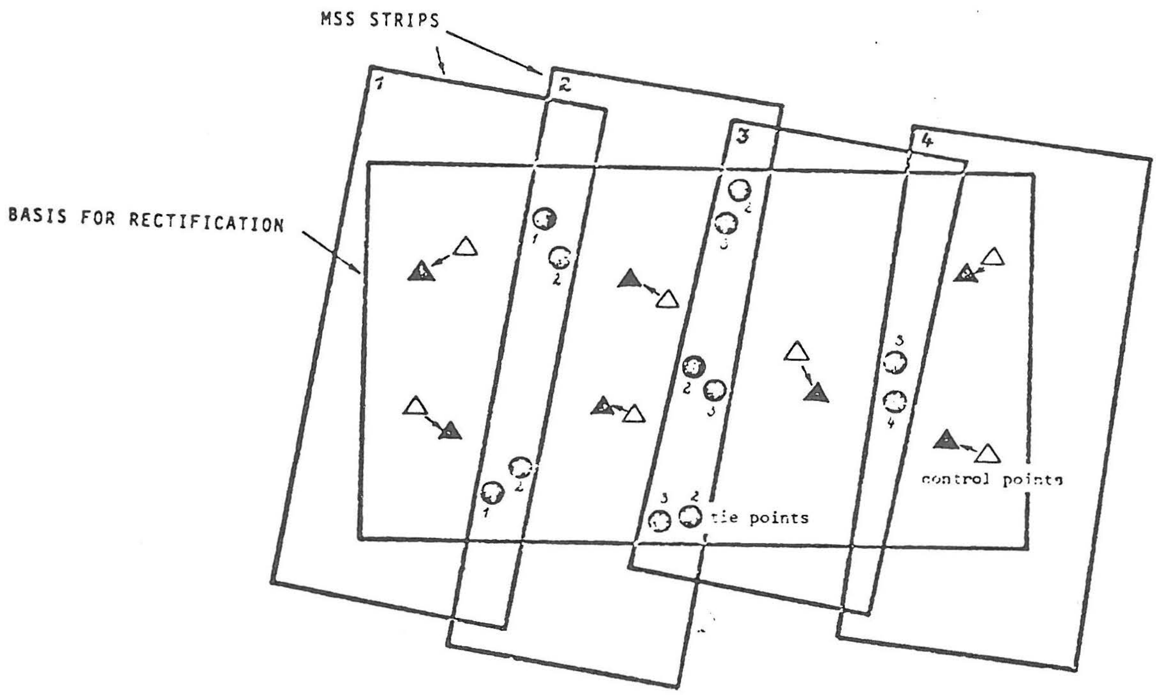
Measurements:

A stereocomparator is used for the measurement of the distortion vectors serving as data in determining the QUINT coefficients. Measured are the coordinates of points identified both on the MSS image and on the rectification base (control points). The rectification base is placed in the left image holder, the MSS image in the right one. Using such arrangement, the parallaxes correspond to image distortions. But because the image holders of a stereocomparator are of very limited extension (23 x 23 cm), and both the MSS image and the rectification base are generally much larger than this extension, measurements are performed sequentially for different parts, so called measurement units. These units are then united by computation, using a three-parameter transformation (rotation, and two shifts). The result corresponds to measuring the entire MSS image and the entire rectification base at once.



Measuremental units

The rectified images have to form a continuous MSS block, meaning that detail parts of which are projected from different strips must remain continuous. E.g. a highway intersecting the borderline of two MSS strips must remain continuous, without any gap in its image. In some ideal case with infinite control points present, this requirement is fulfilled automatically in the result of individual independent rectifications, without additional conditions. In the practice, however, one cannot rely upon the control points only. It is absolutely necessary to assure the continuity by involving so called tie points. Such points are common to two overlapping MSS strips. This purpose is well suited by points exactly identifiable on both strips, without the need of identifying them on the rectification base.



Control points and tie points

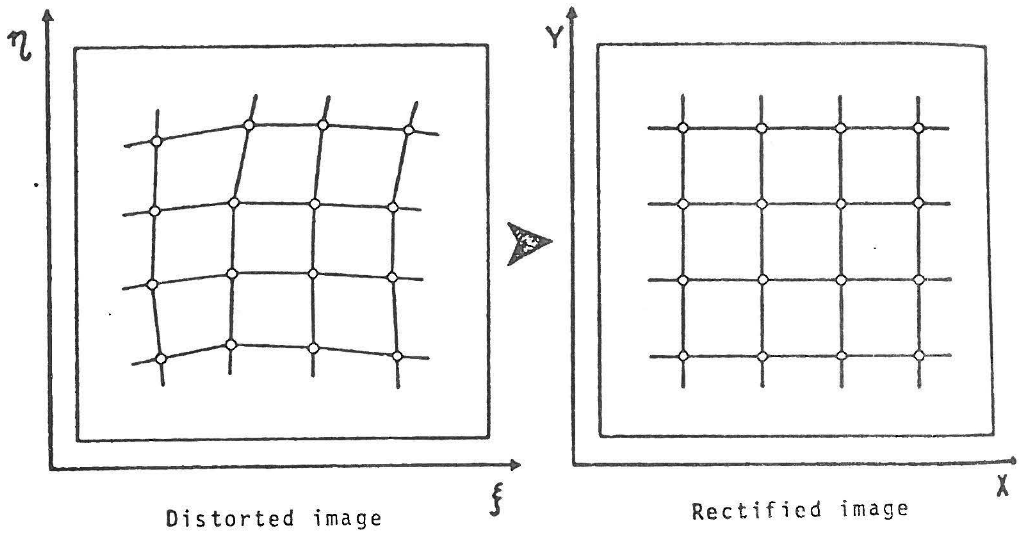
Computation:

The first stage of the computation is the three parameter transformation joining the measurement units to single systems, as mentioned earlier. In the second stage, the coefficients of the least squares interpolation are determined for each strip separately, with the help of distortion vectors in control points. With these, correction vectors are interpolated for the tie points joining different strips, and measured in the MSS images. Each of these points gets two pairs of coordinates, the first pair from one of the overlapping strips, the second from the other. Generally, the corresponding values are close to each other but not equal. Large differences indicate blunders in measuring the coordinates of the tie points in the MSS image, or in one or more of the control points close to the tie point in question. As we cannot know the right value of tie point coordinates, the arithmethic mean is taken as such. Now the second computational stage is repeated: the interpolation coefficients are determined again. But this time, the tie points can be involved in the role of control points, as their rectification base coordinates have been derived. For checking purposes, the correction vectors of tie points are interpolated again. This time, discrepancies are smaller. To make them even smaller, stage two is repeated again and again, until the discrepancies in tie points become smaller than an a priori tolerance. This iterative process converges rapidly. Practice indicates that it is never necessary to repeat it more than three times.

As a result, the interpolating functions are determined, keeping discrepancies in both control points and tie points as small as possible.

5. OPTICAL RECTIFICATION WITH THE AVIOPLAN

The Avioplan is a digitally controlled orthophoto projector. Essentially, it is capable to transform a net of arbitrary quadrilaterals defined in the distorted image into a rectangular grid, corresponding to the rectified image.



The essential principle of the Avioplan

For this, the Avioplan needs the image coordinates of the distorted net written on a magnetic tape. On the basis of these data, the processing computer unit controls the scanning speed, Dove prisms, and zoom lenses of the optical unit, so to assure the right rectification of the image placed in the image holder. This last one is in our case a photographic reproduction of the MSS recording, and the output - the rectified image on photographic material.

Computation of data for the control tape:

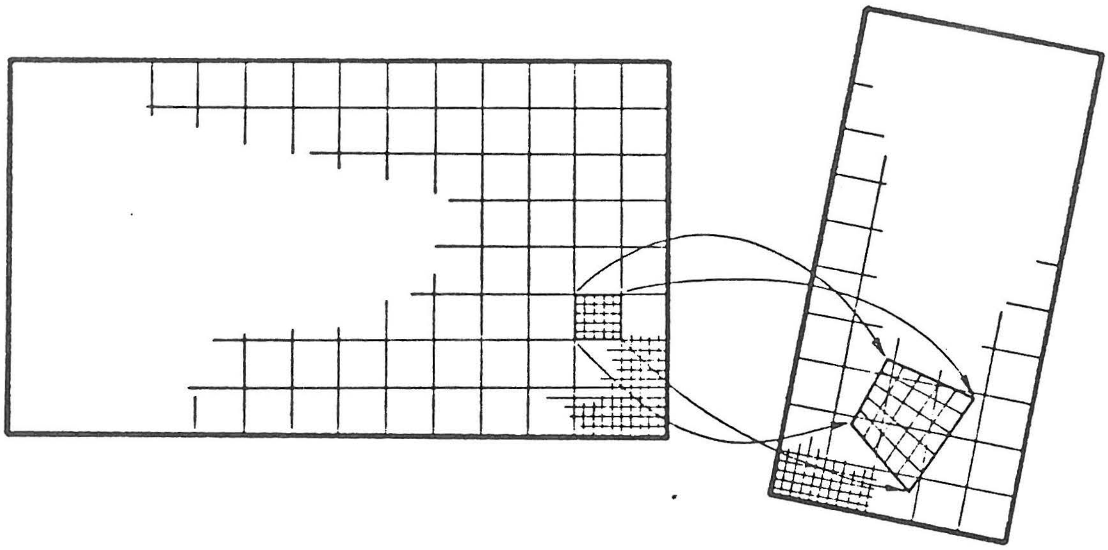
A rectangular grid is first defined in the rectification base. The grid points can then be transformed into the MSS image applying the already determined interpolating functions. These are the coordinates needed by the Avioplan for the rectification.

For the Avioplan, just like the stereocomparator, has an image holder of 23 x 23 cm, the rectification of separate image areas has to be performed in consequentive steps. Should one wish to create a block, these separate areas have to be mounted together manually.

6. THE DIGITAL RECTIFICATION

In this case, the input data are the digitized densities of the distorted MSS strips written on a magnetic tape. The output is written on magnetic tape, as well: the densities of the rectified block. An optical reproduction of the output is necessary only for displaying this way the rectified data on the magnetic tape.

The process of rectification is similar to that within the Avioplan. First, a regular grid is defined in the rectification base. Instead of coordinates of points, we are dealing here with addresses of image elements. With the defined interpolation functions one gets the addresses of the points of the grid in the distorted image.



The principle of digital rectification

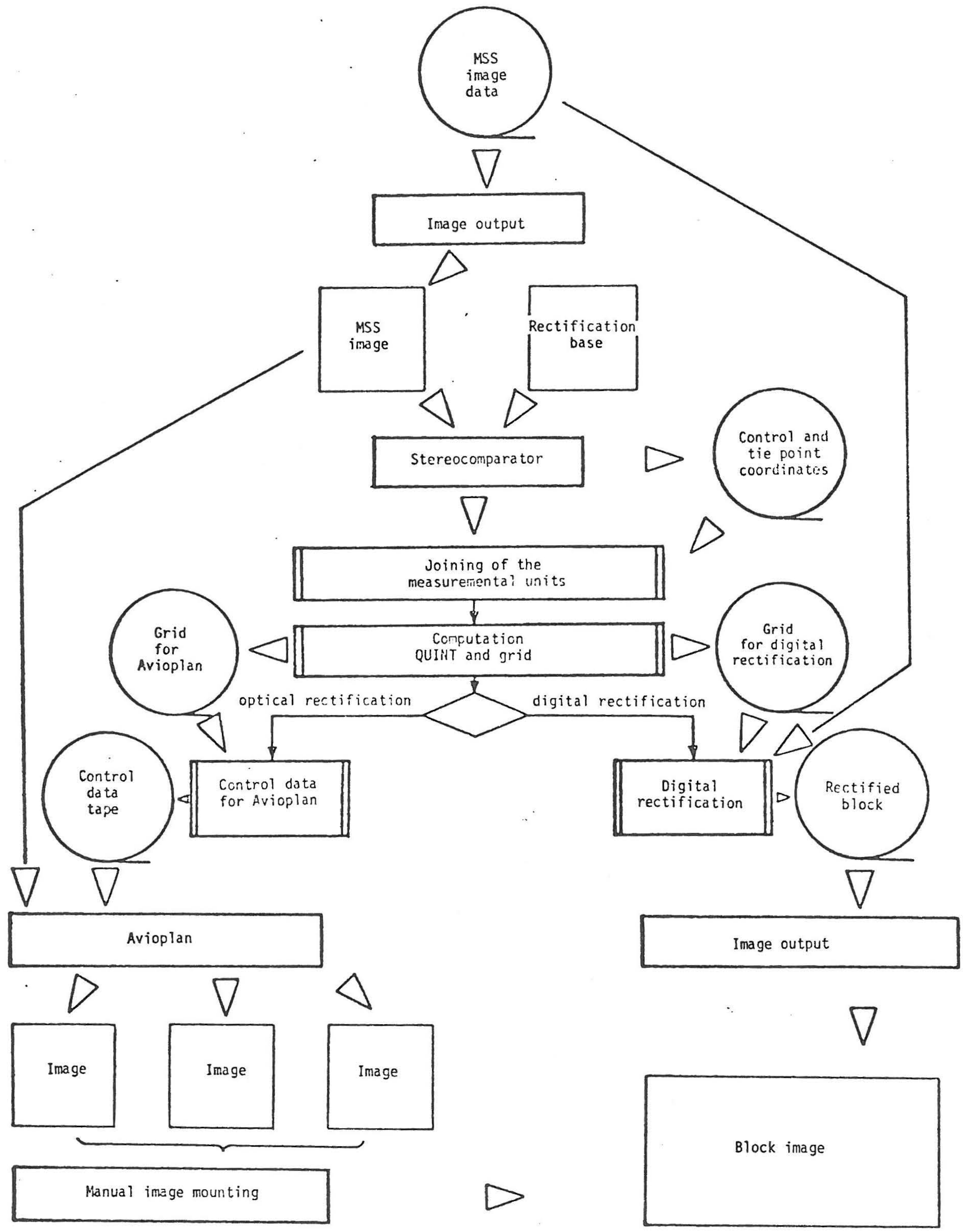
Image elements one by one are translated to their rectified position within the rectification base. Rationally, addresses of intermediate points are determined by applying linear interpolation. To keep the corresponding distortions of the process negligible, the grid must be chosen sufficiently dens. Strips are handled this way one by one.

7. COMPARISON AVIOPLAN - DIGITAL METHOD

Depending upon the application, one or the other way proves to be better. Up to the point of the rectification itself, both procedures require about the same amount of measurements and of computation. The decisive difference of the two techniques lies with the difference of their output. In one case, the output is an optical image, and in the other a digital image written on a magnetic tape.

<table>
<tr><th></th><th>Avioplan</th><th>Digital</th></tr>
<tr><td>Measurements</td><td colspan="2">their amount is depending upon image quality and on the kind of rectification base. With graphical maps as rectification base, control points are harder to choose.</td></tr>
<tr><td>Output</td><td>Optical image</td><td>Digital image on magnetic tape
(can be made optical by a plotter)</td></tr>
<tr><td>Forming blocks</td><td>by mounting the films</td><td>Results are in block form</td></tr>
<tr><td>Rectification</td><td>for each spectral band separately</td><td>all bands simultaneously</td></tr>
<tr><td rowspan="4">Computation</td><td colspan="2">determining the interpolating functions and defining a grid for both ways about the same</td></tr>
<tr><td>no additional computation</td><td>high computer time requirements (especially I/O time) by the rectification process, large mass storage areas needed.</td></tr>
<tr><td colspan="2">required computer time (at a CDC Cyber 74 computer at TU Vienna):
the expenditure of computing time of the first part of programme (determination of interpolation function and computing of the grid) mainly depends on
the number of measuremental units in the block
the number of control points and tie points
the required accuracy at the tie points (number of iteration steps)
the number of interpolated grid points
e.g. project RECKLINGHAUSEN DAY (large block, 7 strips)
33 measuremental units
1 400 control points and 300 tie points
averagely 2 iterations per strip connection
6350 grid points
computer time: 430 CPU seconds
e.g. project GELSENKIRCHEN (3 strips)
3 measuremental units
160 control points and 30 tie points
3 iterations per strip connection
9200 grid points
computer time: 80 CPU seconds</td></tr>
<tr><td>expenditure of work for the rectification with the Avioplan mainly depends on
the time for exact positioning of the image in the carrier of the Avioplan } Avioplan time
the scanning speed } Avioplan time
the number of profiles } Avioplan time
the developing of the film
the mounting of films to a block
e.g. satellite map of Austria 1:500 000
time at Avioplan:
10 - 15 min. per Landsat-scene (1 spectr.bd.)</td><td>the expenditure of computing time of the second part of programme (digital rectification) mainly depends on
the number of computing units (I/O time!)
the size of computing units (number of pixels per computing unit)
e.g. project GELSENKIRCHEN (3 strips)
7900 computing units of the original image
6700 computing units of the rectified image
256 pixels per computing unit
computer time:
24 CPU sec. } reading the original image data
70 I/O sec. } from mag tape and building of comp. units
180 CPU sec. } digital rectification
200 I/O sec. }
20 CPU sec. } changing the comp.units of the
70 I/O sec. } rectified image to the format of the mag tape</td></tr>
</table>

Flow diagram of rectifying MSS images



8. LIST OF PROJECTS

project name	number of strips	size of block (10^6 pixels)	number of contr.pts.	number of tiepoints	number of spectr.bds.	rectification base	computer
Digital rectification:							
HAGEN DAY	1	0.6	60	0	1	map	CDC
HAGEN NIGHT	1	0.6	110	0	1	1:50 000	Cyber 74
HAGEN DAY	4	2.9	350	80	1	-"-	UNIVAC
HAGEN NIGHT	4	2.9	300	40	1		1180
GELSENKIRCHEN	3	1.7	160	30	1	-"-	CDC
OBERHAUSEN	3	1.3	170	40	1		Cyber 74
BIBLIS 1	1	2.3	90	0	1	orthophotomap	UNIVAC
BIBLIS 2	1	2.5	90	0	1	1:5 000	1180
BIBLIS 3	1	2.0	90	0	1		
BIBLIS 4	1	3.5	120	0	1		
BIBLIS 5	1	1.8	50	0	1		
RECKLINGHAUSEN DAY (Large block)	7	1.4	1 400	300	1	map	-"-
(Reduced image data)						1:50 000	
RECKLINGHAUSEN DAY	3	2.2	distortion vectors		1		
GELSENKIRCHEN DAY	3	1.9	taken from large bl.		1		
RECKLINGHAUSEN NIGHT	3	2.2 }	500	70	{ 1	-"-	-"-
GELSENKIRCHEN NIGHT	3	1.9 }			1		
			for determination of distortion computed as 1 block, for rectification divided in 2 blocks				
BRIXLEGG	1	1.3	100	0	11	aerial photograph	PDP 1103
INNSBRUCK MORNING	2	1.2	160	20	2	map	-"-
INNSBRUCK NOON	2	1.2	160	20	11	1:25 000	
INNSBRUCK NIGHT	2	1.2	160	20	2		
Optical rectification:							
SATELLITE MAP OF AUSTRIA 1:500 000	20 LANDSAT-scenes		ca.30 - 50 per scene	ca.5 - 10 per scene	4	map 1:500 000 (conical projection)	CDC Cyber 74

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