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Practical Experience in the Rectification of MSS Images*

The requirements, operational process, applications, and economy of the rectification of multispectral scanner imagery are described.

Abstract: *The elements of outer orientation of the scan lines in a multispectral scan image cannot be determined, at least up to now, with sufficient precision. Rectification based on laws of imagery cannot therefore be applied. The Wild Heerbrug Ltd. Avioplan OR 1 Orthophoto System provides a new solution, as shown by K. Kraus (1978). With this instrument the rectification which is of importance for the practical use of MSS images is now possible.*

The original MSS image is placed in one picture carrier of a stereo-comparator and a line map or orthophoto of the same terrain (a "rectification master") is placed in the other picture carrier. The distortions can now be measured in a number of discrete points and a rectangular reference grid can be interpolated, for example, by linear prediction. The data so obtained are written out on magnetic tape and serve as the input data to drive the Avioplan OR 1.

Experience and results from work already performed in scales from 1:10 000 to 1:50 000 are presented. The following points are particularly discussed:

- *requirements in the MSS image and the rectification master;*
- *magnitude of distortions before and after rectification;*
- *time for processing the examples;*
- *applications of rectified MSS images.*

The results show that there are problems and limits of application of the process. On the other hand the work shows that a very economic, practical, and operational method of rectification of MSS images now exists.

Introduction

More and more frequently photo material which is recorded simultaneously by various sensors in one flight is being used for interpretation purposes. Some geoscientific problems also require images made at different dates in order to study dynamic processes. In both cases the images need to be transformed into a uniform system with known geometry. Although the laws of imagery of the pictures produced by a scanner system are known (Konecny, 1972), it is impossible to determine the distortions of such multispectral scan images (MSS images) at all image points because the flight parameters, and thus the elements of external orientation of each scan-line, cannot be determined with sufficient accuracy.

Kraus (1978)† has suggested a solution to

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this problem. The basic principle of the procedure consists in defining a square grid in the desired image (i.e., the rectified MSS image) and determining the corresponding grid points in the original MSS image (i.e., the MSS image to be rectified) (Kraus, 1976). These latter data, together with the original image, permit a rectified image to be produced in the Wild Avioplan OR 1 Orthophoto System (Stewardson, 1976).

It is never possible to define, *a priori*, the distortion in every point of the original image. Some measurement is necessary in order to determine generalized distortion properties. For this purpose the MSS image is placed in one picture carrier of a stereo comparator and a line map or an orthophoto of the corresponding area (a "rectification master") is placed in the other picture carrier. The distortions are measured in a number of discrete points, which should be distributed evenly over the entire area to be rectified. The distortions of the square reference grid are interpolated by means of the program SORA-MS (Software for *O*ffline *R*ectification, *A*vioplan—*M*SS-images). The method of linear prediction is used in this program (Kraus, 1972). The values thus determined, processed, and recorded on magnetic tape, serve as input data for differential rectification of the MSS original in the Avioplan OR 1. SORA-MS is a self-contained program in the SORA program-packet which is being developed at the Institute for Photogrammetry of Vienna Technical University (Kraus, 1976; Otepka and Loitsch, 1976). SORA-MS is available only in a preliminary version at present.

Practical Examples

The MSS material for all the rectification work mentioned here was produced by Spacetec Ltd., Vienna. The Daedalus Scanner DS 1250 was used. The transformation of the magnetic recordings into photographic pictures was performed in a Daedalus Printer DEI 616. All measurements were made in the Wild STK 1 stereo comparator of the Institute for Photogrammetry. Computation was done in the CDC Cyber 74 of the Computing Centre of Vienna Technical University. Rectification of the MSS images in the Avioplan OR 1 was undertaken by Wild Heerbrugg Ltd.

Table 1 lists parameters of the MSS material. The results of comparator measurements and computations are shown in Table 2. It should be stated here that SORA-MS in its present version is capable of dealing with 280 measured points. If more points are input, the result is an automatic reduction to 280 (see Table 2). The coordinate axes were chosed so that the x-axis coincides with the flight direction and the y-axis is perpendicular to it. The values shown in Table 2 served for the rectification of 11 MSS originals. The technical data are summarized in Table 3. Figures 1-6 are examples of the products.

Practical Experience and Further Development

MSS-Imagery

In all the strips of the Marchfeld mission, covering an area of about 1400 square kilometers and constituting one of the first MSS projects in Austria, the boundaries between areas of different radiation intensities were seen to be sawtoothed in form (see Figures 1 and 2). The cause, according to Spacetec Ltd., was vibration of the sensor during flight. In addition to this fault, which has not occurred in more recent projects, other high-frequency disturbances were occasionally visible in the MSS originals, which cannot be eliminated by the methods and technology dealt with in the present paper. In this context, the techniques of photo-flight for conventional aerial photos may differ from that of flights for scanner images. In the former case it may very well make sense to correct deviations from the flight course between two consecutive photos, but such sudden motions of the aircraft should be avoided during MSS flights because they may produce uncorrectable high-frequency image distortions.

As may be seen from Tables 2 and 3 and from Figures 1 and 2, MSS originals of other wave-length ranges, whose grey tones may be very different from those of classical black-and-white aerial photos, were rectified in the Marchfeld and Essen projects (day flight) by means of the data provided from Channel 11. This economically very interesting possibility involves certain difficulties, however, as variations of speed of film movement in the Daedalus printer result in unequal MSS originals. A first method of subsequent elimination of these difficulties has been realized by Hruska (1975).

Rectification Master

The optimum rectification master is, of course, an orthophoto, for which the aerial photo was exposed in the same flight as the MSS image. This condition involves, however, two economic problems which cannot be overlooked.

First, this method of flying pre-supposes

TABLE 1. MSS FLIGHTS

No.	Project	Purpose. Commissioned by	Flight date	Flight time	Strip No.	Mean scale	Channel	Flown by	Aircraft
1	2	3	4	5	6	7	8	9	10
1	Marchfeld, Lower Austria	Differentiation of fruit types. Mapping of drainage areas. Govt. of Lower Austria	5.8.73	10 h	6	1:44 000	1 – 11	BAfEuV	Pilatus-Turbo-Porter
2	Vienna—Favoriten	Study of applications of MSS for city planning. City of Vienna (MA 41)	6.5.75	9 h		1:10 000	4,6,9, 11	BAfEuV	Pilatus-Turbo-Porter
3	Vienna—Grossfeld-siedlung	Study of MSS rectification and MSS land-use maps. Spacetec Ltd.	6.5.75	10 h	3	1:25 000	4, 6, 9, 11	BAfEuV	Pilatus-Turbo-Porter
4	Essen BRD Night flight	City studies by MSS Siedlungsverband Ruhr-kohlenbezirk	7.8.75	23 h	1022	1:25 000	Dual ×) Thermal	Hansa-Luftb.	Aero-Commander
4	Essen BRD Day flight	City studies by MSS Siedlungsverband Ruhr-kohlenbezirk	8.8.75	10 h	1042	1:25 000	1 – 11	Hansa-Luftb.	Aero-Commander

×) IR 1 = 3-5 μm, IR 2 = 8-14 μm

TABLE 2. DETAILS OF MEASUREMENT AND COMPUTATION

No.	Project	Rectification master	Wavelength (channel) of measured MSS image	No. of measured points	m.s.e. of meas. pts. after Helmert transformation m in ground		Covariance function for linear prediction				No. of gross errors	m.s.e. of meas. pts. after interpolation m in ground		No. in Col. 1, Table 1	No. in Col. 1, Table 3
					X	Y	Constant in X	Exp. in X	Constant in Y	Exp. in Y		X	Y		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Marchfeld	Top. map 1:50 000 enlarged to 1:44 000	8-14 μm (therm IR) Channel 11	185	±133.1	±153.7	0.996	0.0320	0.997	0.0250	0	±15.6	±13.1	1	1,2,3
2	Marchfeld	Cadastral map, reduced to 1:44 000	8-14 μm (therm IR) Channel 11	280	±120.5	±144.5	0.996	0.0320	0.997	0.0250	6	±15.2	±14.8	1	4
3	Vienna-Favoriten	City map 1:10 000	8-14 μm (therm IR) Channel 11	280	±20.3	±16.2	0.997	0.0303	0.996	0.0283	5	±2.5	±2.9	2	5, 6
4	Vienna-Grossfeld-siedlung	City map 1:10 000 reduced to 1:25 000	8-14 μm (therm IR) Channel 11	251	±56.9	±44.3	0.999	0.0262	0.998	0.0265	2	±7.2	±6.2	3	7, 8
5	Essen BRD Night flight	Top. map 1:25 000	8-14 μm (therm IR) Channel 11	280	±67.5	±68.9	0.998	0.0303	0.996	0.0283	0	±6.6	±8.1	4	9
6	Essen BRD Day flight	Top. map 1:25 000	8-14 μm (therm IR) Channel 11	280	±43.8	±27.5	0.997	0.0303	0.996	0.0283	0	±7.1	±8.1	5	10, 11

TABLE 3. DETAILS OF EXAMPLES RECTIFIED IN THE AVIOPLAN OR 1

No.	Project	Scale of rectification	Enlargement from original	Format of rect. image	Channel	Scan width in OR 1	No. in Col. 1 of Table 2
1	2	3	4	5	6	7	8
1	Marchfeld	1:20 000	1:2.2	480 × 254	Channel 11	8	1
2	Marchfeld	1:20 000	1:2.2	480 × 254	Channel 11	8	1
3	Marchfeld	1:20 000	1:2.2	480 × 254	Combination of Channel 6 & 8	8	1
4	Marchfeld	1:20 000	1:2.2	480 × 254	Channel 11	8	2
5	Vienna-Favoriten	1:10 000	1:1	224 × 112	Channel 11	8	3
6	Vienna-Favoriten	1: 5 000	1:2	448 × 224	Channel 11	8	3
7	Vienna-Gross-feldsiedlung	1:10 000	1:2.5	544 × 304	Channel 11	8	4
8	Vienna-Gross-feldsiedlung	1:20 000	1:1.25	272 × 152	Channel 11	8	4
9	Essen, BRD Night flight	1:10 000	1:2.5	592 × 328	Channel 11	8	5
10	Essen, BRD Day flight	1:10 000	1:2.5	592 × 328	Channel 11	8	5
11	Essen, BRD Day flight	1:10 000	1:2.5	584 × 336	Combination of Channel 5, 6, 9	8	6

the existence of a survey aircraft in which both sensor systems, aerial survey camera and scanner, can be mounted simultaneously. The second difficulty during such a flight consists in the differing camera constants of the two exposure systems. If the Daedalus instrument (field angle of the scanning lens = 77° 20′) and a wide-angle lens (f = 15 cm and 23 × 23 cm format) are used, approximately the same strip-width on the ground is covered by both sensors. The scale of the photograph is, however, about twice

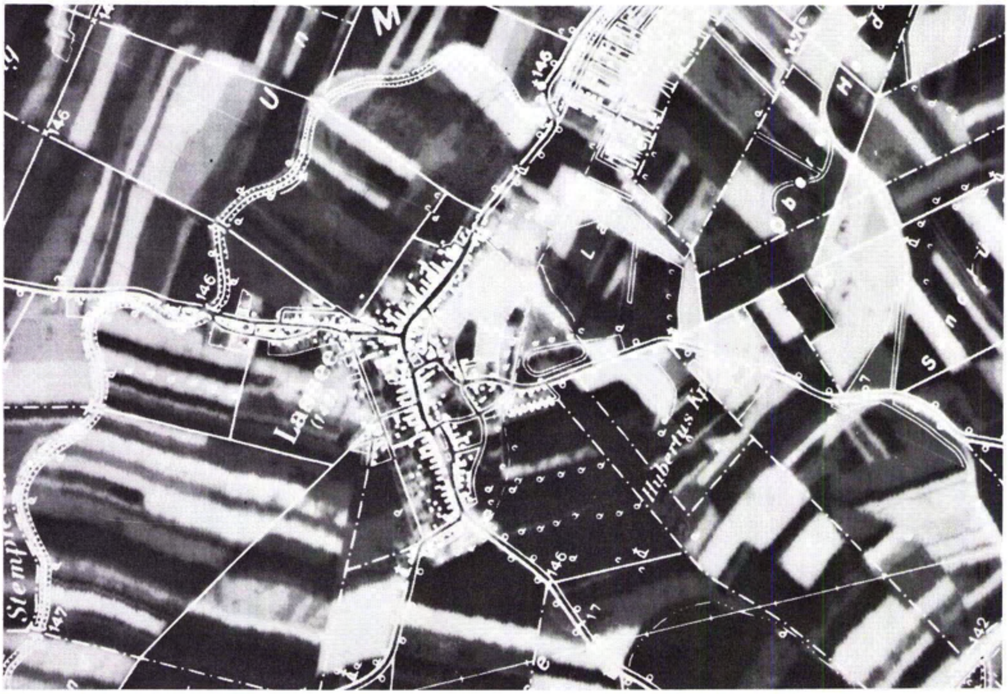

FIG. 1. Extract from rectified MSS image with map details superimposed, scale 1:20 000 (Example No. 1, Table 3). The map details have been enlarged from the standard Austrian Map, scale 1:50 000.

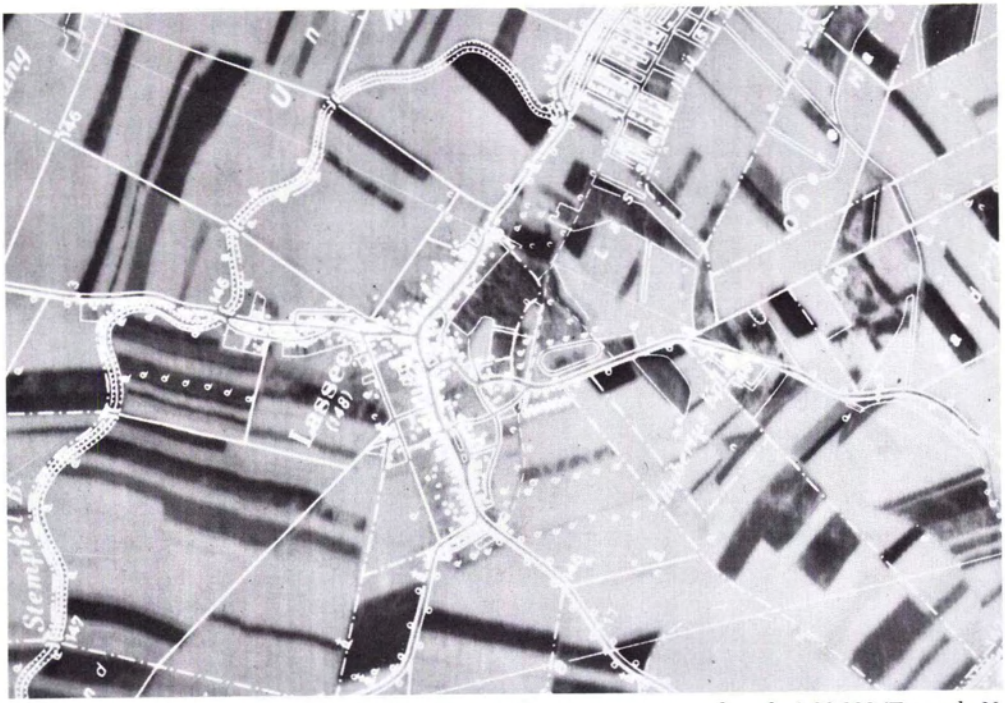

FIG. 2. Extract from rectified MSS image with map details superimposed, scale 1:20 000 (Example No. 3, Table 3). The map details have been enlarged from the standard Austrian Map, scale 1:50 000.

as large as that of the MSS image. As a scale ratio of about 1:3 between the aerial photo and the orthophoto is the optimum, it would be economically unfavorable to use a genuinely simultaneous flight for the production of the orthophoto. It would be considerably more advantageous to make a second flight immediately after the MSS flight, but with a considerably greater flying height.

If data of ground heights have already been stored in a data bank, they can be used to produce orthophotos at low cost (Otepka and Loitsch, 1976) and, furthermore, they can be used to eliminate the distortions in the MSS images, perpendicular to the flight direction, which are functions of differences of ground heights (Kraus, 1978).

MEASUREMENT

For approximate centering of the MSS original in the picture carrier of the Avioplan "fiducial marks" are required. As there are none on the MSS film strips, artifical marks must be made before measurement of the coordinates is undertaken.

The measured points must be distributed as evenly as possible over the area to be processed. The original hope that it would be possible to obtain adequate results with a relatively small number of measured points was not confirmed. For this reason the interpolation procedure in the SORA-MS program is now being changed, so that the still-existing restriction to 280 measured points will no longer be necessary.

Experience during measurement has shown so far that it is extremely difficult to find a large number of evenly distributed points. The use of an orthophoto instead of a line map as a rectification master makes it much easier to find suitable points.

The transformation of the magnetic tape records of the scanner data into photographic images produces relatively long film or paper strips. The rectification masters—orthophotos or line maps—are also usually larger than the usable picture format of 23 × 23 cm of a photogrammetric stereo comparator. Up to the present this format has had to be taken into account for rectification of MSS images.

For future work more suitable equipment seems necessary and the fact should also be borne in mind that the resolution of the aerial photos of classical photogrammetry is far greater than that of scanner images (Konecny, 1975). For this reason measuring instruments are required which are much less accurate than precision comparators, but on the other hand permit larger picture formats to be observed and measured. Such instruments might also be used for observing and possibly measuring orthophotos and their stereomates (Kraus, 1976; Otepka and Loitsch, 1976). For the latter use, however, it must be possible to observe in both transmitted light and reflected light.

DIFFERENTIAL RECTIFICATION

If the MSS strips are longer than 23 cm when measured, they must be cut for rectification in the Avioplan as it is also designed for the format. Since, in the future, reference points outside the 23 cm length can be used in computing the data for the Avioplan, there will be no gaps at the edges of two successive rectified images.

As already briefly mentioned the effects of height differences in the ground have so far not been taken into account during MSS rectification. During the transformation of the magnetic tape data of the scanner into films, a panorama correction is automatically executed by the printer. The correction is, however, only an approximation (Hruska, 1975), so therefore there are still residual errors in the MSS originals. Because of these two errors the data for the Avioplan are always computed so as to make the scanning direction in the Avioplan identical with that during flight.

Columns 13 and 14 in Table 2 show the mean square residual coordinate errors at the reference points after interpolation. Depending on the accuracy desired in the final product, the possible map scale of the rectification can thus be derived immediately. If, for example, a mean coordinate accuracy of 0.2 to 0.4 mm is desired, the scale of the rectification can only be about the same as that of the original, i.e., a ratio of about 1:1. The example Vienna-Favoriten (Favoriten is one of the districts of Vienna) (Table 3, line 5, and Figures 3 and 4) illustrates these conditions.

For many purposes a lower accuracy will suffice. An example is an MSS rectification in a scale of 1:5 000 which will permit identification of lots and comparison with a ground-use plan at the same scale. An original scale of 1:10 000 would certainly be adequate. Naturally there may be local distortions in this case amounting to as much as 1 to 2 mm in the map scale. These distortions are visible if the rectification is compared with the corresponding line plot (see, for example, Figures 1 and 2). The possibility of a thorough accuracy check of a different nature was given by the examples of Essen (West Germany). Two rectified MSS images of the same region could be compared, whose originals had been recorded during two separate flights.

CONCLUSION

The three Essen examples (see Table 3, lines 9 to 11, and Figures 5 and 6) illustrate

FIG. 3. Extract from rectified MSS image (Example No. 5, Table 3), scale 1:10 000.

Fig. 4. Extract from rectified MSS image with map details from the Vienna City Maps superimposed, scale 1:10 000.

the time and manpower required for this type of work. The project was begun on December 1, 1975, and the three MSS rectifications were handed over on December 12, 1975. The time required for preparing, measuring, computing, rectifying, and developing the negatives amounted to about 20 man-hours. It should also be borne in mind that although the measurements and computation were performed in Vienna the rectified images were produced in Heerbrugg, so that some time was necessarily lost. The quoted figures for time and manpower show that a completely operational, very

Fig. 5. Extract from rectified MSS image (Example No. 9, Table 3), reduced to scale 1:20 000. Published by permission of the Regierungspräsidenten Münster, 14. 11. 1975, No. 5229/75.

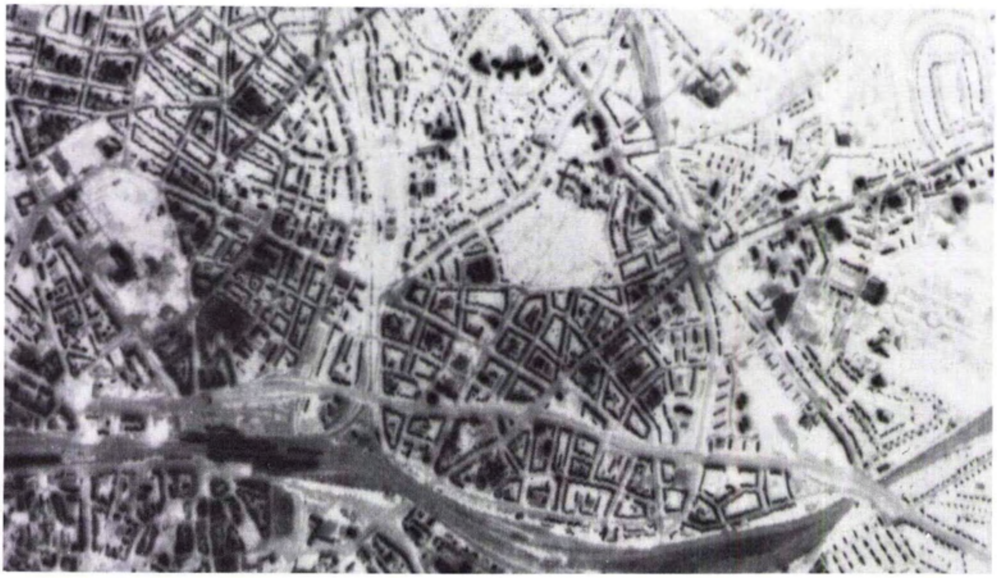

FIG. 6. Extract from rectified MSS image (Example No. 10, Table 3), reduced to scale 1:20 000. Published by permission of the Regierungspräsidenten Münster, 14. 11. 1975, No. 5229/75.

economic, and useful method of rectifying MSS images has been developed.

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