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A DATA BASE TOWARDS THE DIGITALLY CONTROLLED PRODUCTION OF ORTHOPHOTOS

ABSTRACT

The advancement from analogue to digital techniques in orthophoto production resulted in a considerable progress and widening of the field of orthophotography. Contemporary orthophoto production is based upon digital height models (DHM). This enables an almost fully automatic updating of orthophoto maps, provided DHMs are archived in a data base. Supported by a contract from the Federal Department of Standards and Surveys of Austria, the Institute of Photogrammetry of the T.U. of Vienna developed in the recent 3 years the corresponding concepts and the program package TOPIAS (Topographic Information and Archiving Software). Large masses of data (both the results of original data acquiritors transformed in the geodetic system, and the corresponding DHM - a deduced screen of points) are stored on external media (magnetic tapes etc.). The addresses and major description of these data are stored in a permanently accessible information system (residing, e.g., on disc).

TOPIAS is independent of computer types. It is highly compatible with the program package SORA-OPS (Software for Off-line Rectification with Avioplan - Orthophoto and Stereo orthophoto) applied by more than 20 organizations around the globe.

ZUSAMMENFASSUNG

Die Umstellung der Orthophototechnik von der analogen auf die digitale Steuerung brachte einen beachtlichen Aufschwung für die Orthophotographie. Die moderne Orthophototechnik baut auf einem digitalen Höhenmodell (DHM) auf, mit dessen Hilfe die Orthophotokarten nahezu vollautomatisch fortgeführt werden können. Voraussetzung ist allerdings, daß die DHM in einer Geländehöhendatenbank archiviert werden. Das Institut für Photogrammetrie der TU Wien hat im Auftrag des Bundesamtes für Eich- und Vermessungswesen in den letzten drei Jahren eine dafür geeignete Software TOPIAS (Topographische Informations und Archivierung-Software) konzipiert und verwirklicht. Die großen Datenmengen - d.s. die in das Landessystem transformierten Originalmessungen und das rasterförmige DHM - werden auf externen Speichermedien (Magnetbänder usw.) archiviert, und die Adressen der externen Datensätze sowie die Charakteristika dieser Daten werden auf einem permanent verfügbaren Speichermedium (Magnetplatte) in einem Informationssystem zusammengefaßt. TOPIAS ist maschinenunabhängig geschrieben und läßt sich gut mit dem an mehr als 20 Stellen in der Welt verwendeten Programmsystem SORA-OPS (Software für die Offline-Rektifizierung mit dem Avioplan - Orthophoto und Stereoorthophoto) kombinieren.

1. PRELIMINARY REMARKS

The WILD Company presented to the Helsinki Congress of I.S.P. the digitally controlled rectifier Avioplan OR 1 /7/; the corresponding software package, developed under a contract of the WILD Company, was presented to the Congress by the Institute of Photogrammetry of the Technical University of Vienna; SORA-OPS (Software for the off-line rectification with the Avioplan - orthophoto and stereo orthophoto) /6/. This program is now applied in production by more than 20 organizations.

One of the great advantages of this modern technique of orthophoto production, based upon a digital height model of the terrain, is that for areas where such models are present, repeated photographs can be transformed to orthophotos in a nearly fully automatic way. The introduction of the digitally controlled technique of orthophoto production initiated, therefore, a considerable mass production of digital terrain height information. Today, there will be produced probably more digital height models for orthophotos than for other purposes. The Federal Department of Standards and Surveys in Vienna, for example, has digitized about a quarter of the territory of Austria for the purpose of orthophoto production, with a grid spacing of 30 to 160 m. The extensive activities in data acquisition and digitally controlled orthophoto production, described in /3,4/, require an effective data base management program. The Institute of Photogrammetry of the T.U. of Vienna has been developing a corresponding program package under a contract from the Federal Department of Standards and Surveys of Austria.

This data base management concerns not only the digital height models, the management is extended to archives of aerial photography, and to archives of orthophotos. After further extensions, the program package will serve as a general topographic information management system. Correspondingly it has been given the name TOPIAS (Topographic Informations and Archiving Software).

One of the requirements taken into account in structuring and developing TOPIAS is that it should be suited both to large and small computers - a requirement fulfilled in SORA-OPS. Programming is done in standard FORTRAN IV, to achieve minimal dependence on individual systems. TOPIAS will be described here as applied in Austrian circumstances. It can be, however, easily adapted to requirements of other countries or organizations.

2. THE OUTLINE OF THE PROGRAM SYSTEM TOPIAS

Fig. 1 shows the basic version of the program system. The system is suited for both interactive and batch mode of operation. The input of control information is solved by applying the command language DIRAN (Directive Analyzer) /2/. It assures an elegant communication with TOPIAS especially for the interactive user.

The heart of the system is the ADMINISTRATOR. This central section of the program

- channels processing control information to the proceeding programs, and provides them with the corresponding magnetic tapes;
- gives the RUN command for requested programs - as far as this is made possible by the operating system of the computer;
- transfers large data amounts to magnetic tapes;
- collects on a random access file the most important characteristics of data in the form of so called information records;
- provides the user with a convenient way of communication with these information records.

T O P I A S

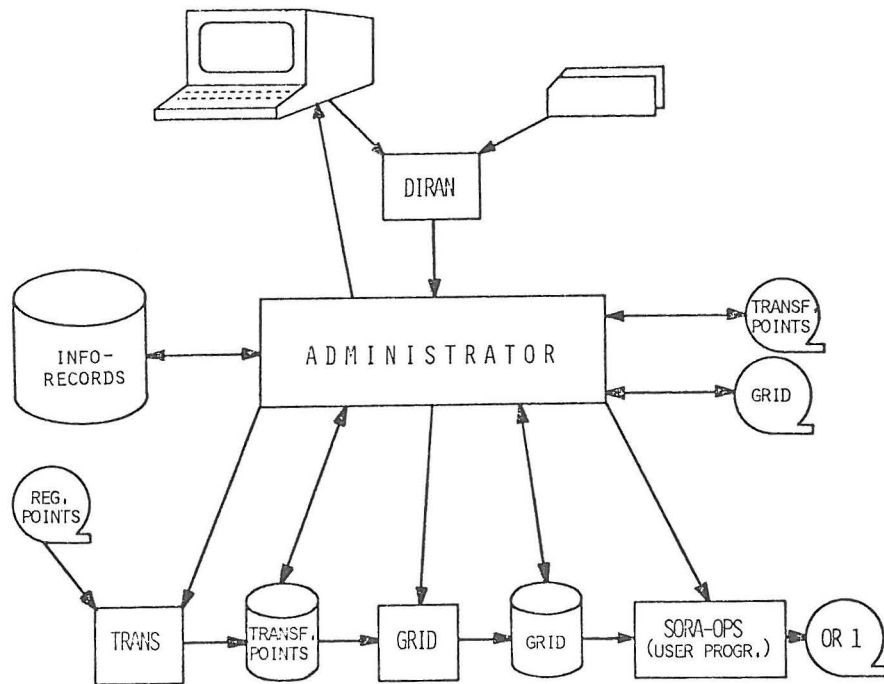


Fig. 1: Basic version of the program system TOPIAS

For an area not yet provided with any digital height model, the ADMINISTRATOR starts first the program TRANS. This program transforms the terrain points written on a magnetic tape into the state coordinate system. The terrain points may correspond to contour lines, profiles, single points and so on, recorded, e.g., past the relative or past the absolute orientation of a photogrammetric model. Transformation constants are determined by the sub-routine MODOR, provided with automatic blunder processing, and with a reliability checking of the results /5/.

The transformed points are written temporarily on a sequential file; they can be transferred from there to a magnetic tape provided by the ADMINISTRATOR. Data of this type - e.g. in the case of digitized contour lines - are valuable for a topographic information system, or they can serve as input for other programs - e.g. in the case of digitized profiles, contour lines can be produced by the program system SCOP of the Technical Universities of Stuttgart and of Vienna. Therefore, recorded terrain point data transformed into the state coordinate system will always be archived on magnetic tapes, and the corresponding information record added to the random access file.

Interpolated heights of a grid of points determined by the program GRID are a further result worth archiving. This grid can be determined on the basis of more than just two models - an important enhancement of the capabilities of the earlier version of SORA-OPS. In addition, GRID provides the user with a set of interpolation algorithms. The grid will be written temporarily to a sequential file, and can be transferred from there to a magnetic tape by the ADMINISTRATOR. The corresponding information record will be extended.

As one of the possible user programs SORA-OPS is shown in fig.1, enabling the production of orthophotos and of stereo mates to them. In this case, the ADMINISTRATOR starts the user program SORA-OPS, and provides it with the magnetic tape containing the archived grid. On this basis, SORA-OPS determines the control data necessary for the differential photographic projection, and writes them on a magnetic tape for the Avioplan OR 1.

Before describing the magnetic tapes with the transformed points and with grids, and before the description of the structure of the information records, it is necessary to treat the nomenclature system that has to be defined for the entire territory of actions.

3. THE SYSTEM OF NOMENCLATURE

For Austria, the state coordinate system (UTM with 3° strips, zero meridian in Ferro) is subdivided in 10km x 10km squares (referred to as "10km-squares", fig.2). Each 3° strip is provided with a rectangle containing the corresponding area of activities. The wide overlapping zones of these rectangles allow the handling of even very large projects using only one UTM strip.

The 10km-squares are addressed, as shown in fig. 2, by numbers increasing to the right and upwards. Beside the addressing level for the 10km-squares, which is referred to as dominant, there are other addressing levels defined, for 5km-squares, 2.5km-squares and so on. The nomenclature for these levels consists of the dominant address of the 10km-square, and of an addition to it. E.g. the city of Salzburg is to be found in the 10km-square 4330, and within the 5km-square 4330- 1 (the 5km-squares are numbered 0 and 1 in the upper line and 2 and 3 in the lower line).

In the first line the organization of the information records have made it necessary to introduce still another, highest level of addressing - for 30km-squares, shown in fig. 2 by thick solid lines.

All the addressing levels used in Austria are collected in table 1.

square side (km)	Number of such squares within squares of some higher level	Number of such squares altogether
30		220
10	9 within a 30km-squ.	1 980
5	4 10	7 920
2.5	4 5	31 680
1.25	4 2.5	126 720
1	25 5	198 000
0.5	4 1	792 000
0.25	4 0.5	3 168 000

Table 1: addressing levels

During the installation of the program system TOPIAS on some computer, there have to be specified: the dominant addressing level, the number of levels higher and lower of the dominant level, and the sides of squares of each defined level. TOPIAS applies a much more compact internal addressing; small subroutines are used for conversions between the two addressing systems.

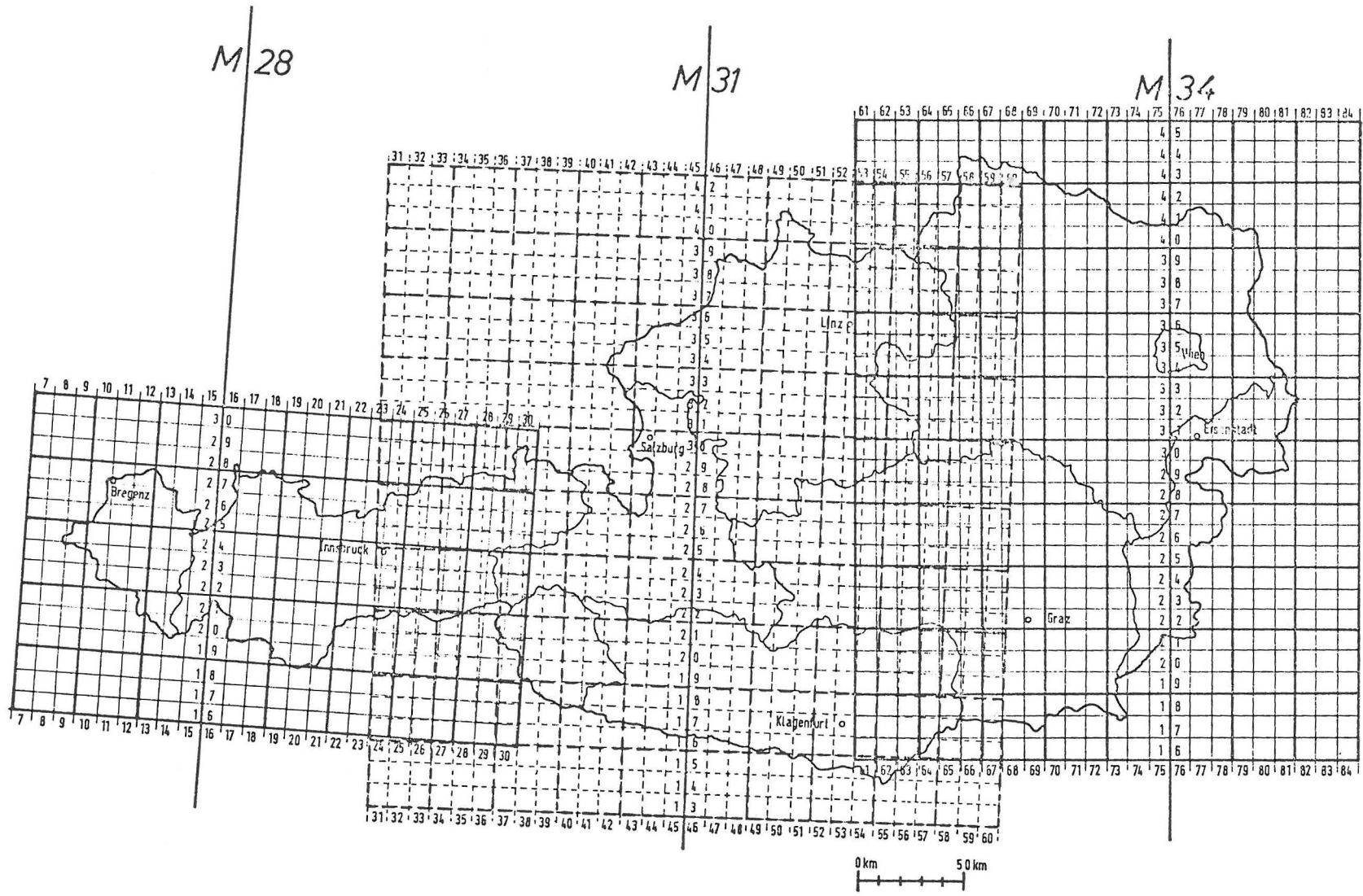


Fig. 2: The system of nomenclature for Austria

square sides (km)	orthoph. scale	standard grid widths (m)										
		120	150	187.5	240	300	375	468.75	600	750	937.5	1200
30												
10		40	50	62.5	80	100	125	156.25	200	250	312.5	400
5	1:10 000	20	25	31.25	40	50	62.50	78.125	100	125	156.25	200
2.5	1: 5 000	10	12.5	15.625	20	25	31.25	39.0625	50	62.5	78.125	100
1.25	1: 2 500	5	6.25	7.8125	10	12.5	15.625	19.53125	25	31.25	39.0625	50
1	1: 2 000	4	5	6.25	8	10	12.5	15.625	20	25	31.25	40
0.5	1: 1 000	2	2.5	3.125	4	5	6.25	7.8125	10	12.5	15.625	20
0.25	1: 500	1	1.25	1.5625	2	2.5	3.125	3.90625	5	6.25	7.8125	10

Table 2: standard grid widths

Before archiving a grid, heights are averaged on the border lines with other squares of the same addressing level. Accuracy characteristics of the grid gained in the process of averaging are recorded in the header of the grid. Messages are sent to the user whenever insufficient accuracies occur. - Should the necessity of averaging grids for different levels be indicated by applications, it will be realized then at a later time.

Standard grids of all addressing levels of a 30km-square will be archived on one magnetic tape and eventually on its continuation tapes. It is possible, however, to join the archives of some 30km-squares and to write them onto the same tape.

The header of a standard grid contains the following main information:

- nomenclature corresponding to the specified addressing level,
- grid width - a submultiple of the corresponding square side,
- the applied method of interpolation (moving surface methods, prediction etc.),
- structure of the archived data (see section 7),
- accuracy characteristics gained by averaging on the borders,
- magnetic tape and file numbers.

6. INFORMATION RECORDS

The ADMINISTRATOR collects on a random file the following information records:

6.1. Project information records, with the main contents:

- Project code (number or code),
- project name (e.g. owner or compiler),
- date,
- project limits, defined either as the nomenclature of squares of any level, or as a surrounding polyhedron defined in the state coordinate system,
- coordinates of control points in the state system,
- the information for each archived model of the project similar to that described in section 4.

Project information records are structured in accordance with the 30km-squares. Projects subdivided by borders of such squares are registered in the square where the largest part of the project area belongs, and the corresponding address will be noted in the other square(s).

4. ARCHIVING THE TRANSFORMED POINTS

The points transformed in the state coordinate system are modelwise archived on magnetic tapes. Generally, a separate magnetic tape is designated for each 30km-square. It is however possible to write more than one of such squares on one tape, when this has been so defined within the ADMINISTRATOR. This possibility is advantageous for squares on the periphery, in the overlapping zones of the meridian rectangles, or for small terrain units belonging together (e.g. city areas divided disadvantageously by the 30km-square borders). On the other hand, if a magnetic tape has all the models written on it (as defined by the user), the ADMINISTRATOR generates the address of a continuation tape for further models of the square(s) to be archived.

Each model archived on a tape starts with a header containing the following main information:

- model number, independent of any other addressing (e.g. of the nomenclature of the squares),
- model limits, defined either as the nomenclature of a square of any level, or as a surrounding polyhedron defined in the state coordinate system (as a series of coordinates, as a rectangle parallel to the axes of the state coordinate system, or as a rotated rectangle),
- the compiling photogrammetric instrument, the way of data acquisition (contour lines, profiles etc.), point density,
- control point coordinates both in model- and in state coordinate systems, to allow transformations back into the model system, or into another reference system; and accuracy characteristics of the absolute orientation of the model will be recorded in the header, as well,
- magnetic tape and file numbers,
- description of the structure of the archived data.

The structure of the archived data is connected with the stand of their processing. The simplest structure corresponds to the stage where points are transformed into the state coordinate system, and without any change in their order or coding are written on the magnetic tape. Other structures of transformed points are mentioned in section 7.

5. ARCHIVING OF INTERPOLATED GRIDS

The points transformed into the state coordinate system are always archived - even if they are not provided with nomenclature; interpolated grids, on the other hand, will be archived only if they cover the entire square specified in the nomenclature. Grids are stored as parallel profiles all running upwards. Grid widths must be submultiples of the corresponding square side. Table 2 contains a summary of such grid widths. Orthophotos are produced in Austria for square with sides $\leq 5\text{km}$; for them, table 2 specifies the orthophoto scale corresponding to a format $50 \times 50 \text{ cm}^2$.

In cases where the standard grid width does not suit as slit width for the orthophoto projector, another grid has to be interpolated with a corresponding width, on the basis of the (archived) standard grid. If an orthophoto has to be produced with borders identical with the sides of the standard square, it is advisable to request the interpolation of a new grid covering an area somewhat larger than that of the standard square. This is necessary to assure the sharpness of the image on the peripheries of the orthophoto.

6.2 Aerial photography information records, with the main contents:

- code, name, date, and limits similarly to the project information records,
- camera (objective, focal length, format),
- photo scale,
- film (black-and-white panchromatic, false color etc.).

Aerial photography information records are structured in a way similar to that of the project information records.

6.3 Standard grid information records with the information as explained in section 5. The organization of these records is such as to facilitate a fast extraction of standard grid data of any neighbouring 30, 5 and 2.5km-squares, all over the country. The same is true for extracting standard grids of the same area but belonging to different addressing levels.

Standard grids for orthophotos 1:2 500, 1:2 000, 1:1 000, and 1:500 with corresponding square sides ≤ 1.25 km, are not directly addressable for the entire area of the country. These standard grids are limited to city areas and other areas of intensive use. Therefore, the concatenation of all of them over the entire area of the country is not necessary (within the same low addressing level). However, if TOPIAS is applied as data management system for some city area, where such concatenation becomes necessary, this has to be specified at the time of installation.

6.4 Magnetic tape information records describe the mutual correspondence among 30km-squares and tapes. As mentioned, there may be more than one of such squares written onto one tape, and, on the other hand, full tapes can be followed by continuation tapes. Magnetic tape information records have to be created both for archives of transformed point records, and for archives of the standard grids.

6.5 Orthophoto information records contain information on both those orthophotos created within the framework of the nomenclature, and those created independently of it. For each orthophoto, the following main information will be stored:

- orthophoto number, corresponding to the nomenclature or independent of it,
- slit width, which does not necessarily coincide with the standard grid width,
- sort of the orthophoto (black-and-white, false color, etc.),
- orthophoto scale,
- the limits of orthophotos which have been created without specifying the nomenclature, in the form of an eventually rotated rectangle, defined by coordinates in the state coordinate system.

6.6 Auditing the information records

Information records can be audited according to some identification of a project, of some aerial photography, or of the area of interest. In this, "area of interest" may have the extreme meanings of identifying some small section of the terrain, even of some single point, or, on the other hand, of the entire area as represented in the records. Depending upon input parameters, the (interactive) play of questions and answers can be subdivided into four major sections.

a. Input: project code or project name. Searching algorithms can then be started one-by-one to extract the following information, in the form of answers to (interactive) questions:

- Limits of all models within the project. Graphical output of these limits

on screen or printer applying the quick-plot routine developed by L.Molnar. It is planned to develop an output on plotters.

- Codes, names, dates etc. of aerial photography connected with the project.
- Control point coordinates eventually requested by the number of the point(s).

b. Input: Code or name of the area covered by aerial photography.

Similarly to a., the following information will be extracted in answer to the corresponding (interactive) questions:

- Limits of the area covered by aerial photography, date, camera parameter, photo scale, film sort.
- Orthophotos produced, corresponding slit widths, borders of the area covered by them (in cases when they do not cover the entire squares).

c. Input: area of interest, defined by nomenclatures or by coordinates of points in the state system. Answers to the specified questions may be:

- Project codes and dates; if so specified, only projects belonging to a given period; for projects only partially belonging to the specified area of interest, border lines of the part within this area will be plotted on the screen or on the print-out.
- Information similar to the previous one for aerial photography complete with camera parameters, photo scales, and film sorts.
- Standard grid numbers and its characteristics, corresponding to a specified project, complete with magnetic tape and file numbers. A grid chosen and control points of a project can then be passed to SORA-OPS to determine and output the control information for the production of an orthophoto.
- If the answer to the previous question was in the negative (no standard grid for a certain flight and project), one can request the listing of model numbers and of the corresponding magnetic tape and file numbers with transformed points into the state coordinate system. In case of a positive answer, the programs GRID and SORA-OPS can be started.
- For a specified period of time concerning aerial photography output of a listing of orthophotos of a certain (specified) scale belonging to the area of interest, complete with their numbers, aerial photography codes, and the dates of the flights.

d. Finally, the following questions can be put to the ADMINISTRATOR, concerning the entire area of activities:

- What aerial photography have been completed in the year specified?
- Of which aerial photography have there been created any false color orthophotos?
- What project codes belong to a certain project name (e.g. name of a certain owner)?
- Where are there any standard grids belonging to a certain addressing level?
- Where are there any transformed points corresponding to photography of a certain scale interval?
- How many models have been compiled on a certain stereocompiler instrument in form of contour lines?
- Which models have yielded standard errors in their absolute orientation worse than a specified accuracy level?
- Which standard grids have shown an inaccuracy exceeding a specified level, in the process of height averaging on their borders?

7. SOME EXTENSIONS

Beside SORA-OPS, there exists a second "user program" (written by L.Molnar), that can be started via the ADMINISTRATOR. It is creating plots of contour lines digitized on a stereocompiler instrument or with a digitizer. The program uses as input the transformed points in the state coordinate system, and archived on a magnetic tape. It searches for contour line sections, and after curve interpolation and re-coding writes them and their heights on a plot file, within the frames of a map sheet. At this time, files can be generated for plotters of the firms Aristo, Benson, Calcomp, Contraves, and Kongsberg.

We are in the process of integrating the contouring program SCOP within TOPIAS. First of all, common rules of data coding and recording had to be created for SCOP and for TRANS (fig.1) /1/. Second, a conversion program is being written, to allow data communications between the file with the transformed points in the state coordinate system, and the so called "datafile" of SCOP. The datafile is a random access structure that will be used, beside SCOP, by the programs written, correspondingly by E. Assmus and by L. Molnar:

- UPDATE for correcting and editing the data /1/, and
- PLOT for a manysided graphical representation of the data, using different output devices.

The data coming from the SCOP datafile possess a structure superior to that of the transformed points created by TRANS. The archiving of both of these data is possible in the same way, with noting the differences in their structure in the header of the data set (section 4), and in the corresponding project information record. Furthermore, archiving the SCOP-grid will be made possible. This grid contains, besides the heights of the points of the grid, heights of intersections of the lines of the grid with recorded breaklines of the terrain. In addition, these points are arranged in computational units rather than in profiles. These specialities of the structure have to be noted in the corresponding header and in the corresponding information record.

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