OR-1 LINKED WITH A PDP-11 MINICOMPUTER

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Abstract

At the ITC a WILD OR-1 has been linked with a PDP-11 mini-computer instead of the NOVA computer which is usually delivered by WILD. The increased computational power and background memory permits an extension of the system capabilities. It is possible for example to produce orthophotos and stereomates directly from a DEM without the use of another computer. Moreover, the photo-coordinates of the ground control points needed for calculation of the transformation parameters, can be measured directly in the OR-1. "Facet-rectification" and "rectification of scanner images" by polynomials is also possible.

This paper describes the present configuration and the existing programs and outlines the additional software to be developed. Further, the advantages of the described system in practical use are discussed and compared with the standard configuration (and the commercially available software).

Introduction

The first ITC concepts on digitally controlled off-line orthophoto printing date back to the beginning of 1969 [1]. When the OR-1 was realised by Wild in 1976 its hardware was capable to implement most of the ITC's concepts, apart from the computer used for the process control. Its power was insufficient to carry out any additional tasks. Therefore the ITC purchased the optical-mechanical unit and the control electronics of the OR-1 and interfaced it, in close cooperation with WILD, to a PDP-11 minicomputer.

At first a PDP-11/10 was used with one hard disk and one mag.tape unit. This configuration was quite adequate for the intended purpose, but for other, non-technical, reasons it was replaced by a PDP-11/45 with 2 hard disks and 2 mag.tape units and other peripherals. The software had to be developed fully by the ITC. The information needed on the hardware was supplied by WILD.

The objective of this developement was to enable the system to produce orthophotos and stereomates directly from terrain data. This terrain data could be either a limited number of irregularly distributed terrain points which describe the terrain by facets, or a regular grid DEM. With this approach it is not necessary to produce a different set of data for each product to be made. With the same input data set, an orthophoto or a stereomate can be made of a certain area, even from different photographs, at different scales or with different slits.

In addition the measurement of photo-coordinates of the ground control points by external means (e.g. comparator, coordinatograph or cartographic digitizer) and the empirical orientation of the photograph in the OR-1 are replaced by direct measurement of the control points in the OR-1. Also geometric correction of strongly deformed images like LANDSAT-MSS photo-graphs is possible without the use of another computer.

Hardware

The present hardware comprises (figure 1):

1. A standard WILD OR-1 [2] without the NOVA-computer and the mag.tape unit. The console terminal is replaced by a DEC terminal (VT100) and the three interface cards in the electronic cabinet are replaced by a single card ("PDP-option").

2. Five flat cables for 16 bit parallel data transmission

3. Interfaces at the processor side:
   - 1 x DR11-L 2 word (16 bit each) input unibus
   - 2 x DR11-M 2 word (16 bit each) output unibus

4. A PDP-11/45 computer with 2 disk units (RK05), 2 mag.-tape units (800/1600 bpi) and 64k word (16 bit) MOS memory.

The Interface at the OR-1 side of the transmission cables is the card "PDP-option" which was developed jointly by WILD and ITC and produced by WILD.

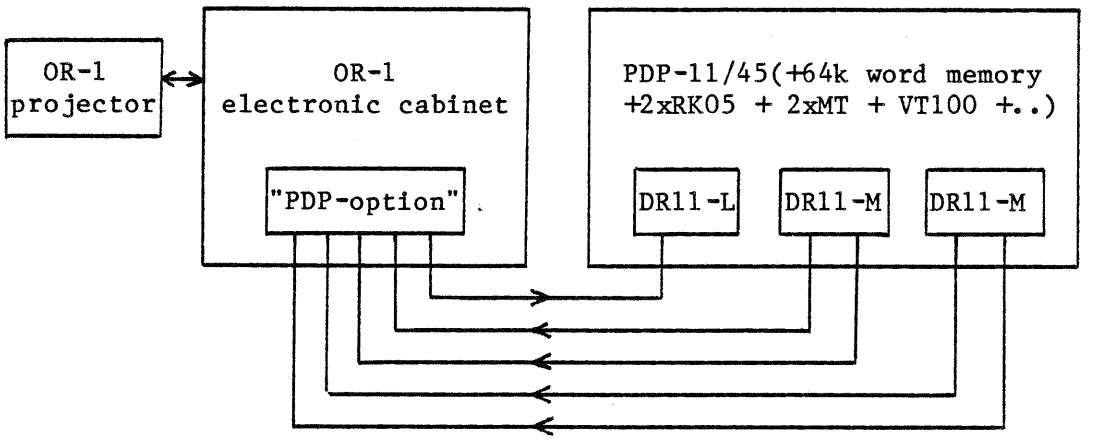


Figure 1

In fact a much slower processor (a PDP-11/10 was used at first) with one hard disk, 32k word (64k byte) memory and a mag.tape unit would be sufficient. Presumably even a LSI-11 with floppy disks would do, provided that a mag.tape unit is connected to it.

Software

In 1976 T. Bouw of ITC, developed a "machine independent compiler" for a language which is basically a subset of PASCAL with some extensions e.g. to facilitate the easy incorporation of macro (assembler) routines. This compiler produces a code for a "virtual

machine", the P-code. At the execution time of the program the P-code is interpreted by a threaded code interpreter. To execute macro routines the interpretation mode is temporarily abandoned.

The scan routine is time constrained - it computes the four control parameters for the OR-1 (X-mean, Y-mean, rotation and scale) from the coordinates of two points, interpolates (99 times) between the parameters of adjacent line elements and outputs interpolated values on interrupt. There may be up to 3000 interrupts per second and the routine is therefore writen in macro (assembler). Some very small routines are also programed in macro, merely for convenience.

All the other software for the OR-1 is written in the PASCAL-like language mentioned above including a "mag.-tape handler" and a "Teletype handler". It is therefor "machine independent". The programs are interactive and are basically controlled by one-letter commands from the keyboard.

At present there are three programs operational, namely:

1. Program "OR1" which enables the OR-1 to operate almost the same as a standard Wild version. Inputs are the image-coordinates of the profile points from the mag.-tape. The program was written by T.Bouw in cooperation with the author.

2. Program "SAT" provides for geometrical affine transformation of images. Inputs to this program are the image coordinates measured on the OR-1 (under program control) and a file containing the ground coordinates of the control points.

3. Program "FACET" produces orthophotos of terrain which can be well approximated by a small number of triangular (plane) facets. Inputs to this program are the image coordinates measured on the OR-1 (under program control) and a file containing the ground-coordinates of the control points and the data describing the terrain by facets.

The modules for coordinate measurement, spatial resection, transformation and facet interpolation for the programs SAT and FACET were programed by B. Kunji of ITC.

The three programs have many parts in common and so an attempt will be made to combine them into an overall program. It is also intended to extend the software such that orthophotos and stereomates can be produced directly from a regular grid DEM (terrain profiles). This requires programming of the input of the DEM-data, interpolation (e.g. linear) of intermediate profiles and the interpolation of points along profiles for stereomates. All other parts exist already in the program FACET.

The input of DEM-data depends on the form (format, structure, medium) in which they are stored or presented to the program. A concensus about this form has to be attained before this part can be programmed.

The introduction of artificial parallaxes to produce stereomates is only possible in the direction of the profiles (i.e. forward or backward), therefore the direction of the profiles should agree with the flight direction (within a few grades).

The geometric correction for regularly distorted images is at present only by affine transformation. In future it will be extended up to a third degree polynomial correction.

Operational considerations

A standard OR-1 (also the ITC version with the present program "OR1") requires input from a magnetic tape. It consists of an identification number, the scan length, the slit width, the photocoordinates of three orientation points and the "image profiles". "Image profiles" are a list of photo coordinates of those points which should be imaged at 1 mm intervals along the scan lines in the orthophoto.

Such tapes can be produced directly by scanning stereo models in a photogrammetric plotter which is specially equipped for this purpose with a tracking system and a recording device for photo coordinates (e.g. WILD PE3 + PBK11 [+PAZ1]). The recorded data can only be used for the production of an orthophoto with fixed scale and fixed slit size from one specific photograph. Stereomates can not be made with this system. The area must be re-scanned to produce an orthophoto from a different photograph or with a different slit size or at a different scale.

Another way to produce the required input tapes is to use a digital computer to convert any height information into the necessary "image profiles". There are programs available for the production of orthophotos, stereomates and other kinds of geometric image transformations, e.g. the SORA programs [3],[4]. To find the transformation parameters these programs require (amongst other data) photo coordinates of control points. These coordinates can be measured directly in the new Wild version of the OR-1. Subsequently the data must be transferred to a computer provided with the SORA programs. To be able to abandon the empirical orientation of the photograph, the OR1 must be left idle until the SORA processing is ready and the magnetic tape is transferred. Then the production on the OR-1 can start.

There is no time lack between measurement of the control points on the OR-1 and production of the orthophoto (or other product) in the ITC approach. The measurement of up to 10 points does not take longer than an empirical orientation. This is because prepositioning is done by the computer after the measurement of the first two points. Only very small manual corrections are required after the third or fourth point if there were no blunders in the first measurements. Blunders can be eliminated interactively.

For perspective, affine or polynomial image transformation the computations are very easy and therefore an external computer is not needed. All the system needs is a ground control file, measurements

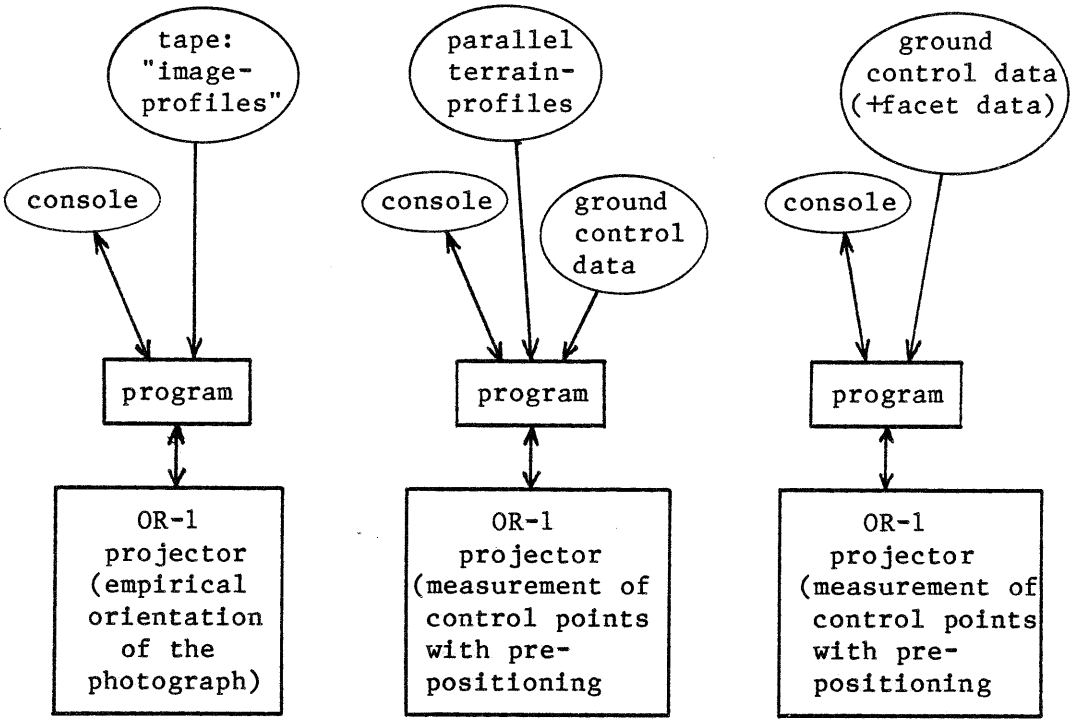
of the control points on the OR-1, input of slit size and scale for the image transformation, and the definition of the area (by ground coordinates or by points measured on the OR-1).

The computational effort is somewhat higher for facet-rectification but it does not require an external computer. The most time consuming part is the preparation of the topological data which defines the facets. It is therefore only feasable for smooth terrain, where ordinary rectification is not good enough. At present the program limits the number of points to 40. When more points are required to describe the terrain properly profiling is probably to be prefered.

The interpolation of regular profiles from an arbitrary DEM is however too time consuming to be done in real time or between adjacent scans. The input data for the program which controls the OR-1 must be conditioned so that the computations during the scan operation are not too involved. Programs must be available to transform an arbitrary representation of the terrain elevations (arbitrary DEM) into regular profiles. Such programs (like HIFI-P or the first part(s) of SORA) are normally too large to be run efficiently in a minicomputer. They should therefore not be installed on the computer which controls the OR-1.

Orthophotos and stereomates can be produced immediately with the ITC version after a reflight of an area (and stereoscopic point transfer of control points if the ground control was not signalised).

The conversion of arbitrary DEM data to parallel profiles needs to be done only once for a certain area. If the area covered by one project is too large for storage in one file, these regular profiles should be segmented into patches. It should be possible to produce orthophotos and stereomates covering several patches without the use of an external computer.



standard OR-1

intended ITC OR-1 (differential rectification)

present ITC OR-1 (facet rectification and polynomial image transformation)

Conclusions

The difference between the ITC-approach and the standard OR-1/ SORA system is not very striking if a single orthophoto has to be produced from an arbitrary DEM. The major differences are: On line (computer supported) measurement of control poins including detection and elimination of blunders, no empirical orientation of the photograph and the input data should be kept for possible future use.

The difference becomes more pronounced however, if stereomates should also be produced, or if orthophotos (and stereomates) from different photographs and/or at different scales of the same terrain should be produced. This can be done with the same input data, so that no external computer is required once the file of regular profiles exists. Besides the actual production in the OR-1 there is no extra work required for an additional product of the same terrain.

There is no need of external computation for polynomial- or facet-rectification. This speeds up the entire process considerably. At present it is not the intention to program cylindrical, or conical etc. projections, although this could be done if there is a need for it. In some cases a polynomial rectification might be used instead.

References

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