INTERACTIVE DIGITAL STEREO-PLOTTING

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1. Introduction

The classical instruments for stereo-plotting and map revision are still the stereo-plotting instruments. These instruments are conceived in an optimal way for the observation and measurement in aerial photographs; a certain difficulty arises however when the document, which is produced on a lateral positioned plotting table has to be compared with the content of the photographs. The only reference between map and aerial photographs is the floating mark of the plotting instruments, respectively the pencil on the tracing table. Although this situation might be completely satisfactory for initial plotting, severe difficulties might result when aerial photographs have to be inspected for changes for map revision. In the past there was certainly no deficiency on trials to create better conditions for the comparison between aerial photographs and maps. One should be reminded, in this context, of the development of the Zeiss Double Projector, the Zoom Transfer-Scope of Bausch & Lomb or the Fazet Plotter of Yjzermann. Although these instruments have had a considerable commercial success they cannot claim to have satisfied the aboved-mentioned requirements.

The general disadvantage of all these instruments is a strong deterioration of the image quality of the photograph due to the image injection. On the other hand the differences in the geometry of the map and the aerial photographs require very time consuming manipulations. In a much more efficient way, a direct comparison between aerial photographs and map can be obtained by the use of orthophotos. Furthermore the technique of digital mapping opens completely new possibilities for interactive photogrammetric plotting.

2. Use of orthophotos

Doubtlessly, among the enumerated possibilities the best studied methods are in connection with orthophotos. Various national mapping institutions use orthophotos on a routine basis for map revision. Advantages are the relatively simple working methods as soon as the orthophotos have been made. The disadvantage of orthophotos is a certain loss of image quality by the process of the orthophoto production and the lack of the possibility of stereoscopic observation, although it is well known that there are possibilities to produce a stereomate and then observe orthophotos stereoscopically. However in this way the very simple manipulation of orthophotos is to a considerable extent lost. It is well understood that the orthogonalization of an orthophoto can never be exact and buildings, certain changes of slopes, dam sites and other similar objects will always show systematic displacements. These are effects which should be taken into account for large scale orthophotos between 1:1000 and 1:5000.

3. Projective transformation

The geometric adaptation of map and photographs can be achieved in an exact manner when the map content is transformed into the geometry of the aerial photographs. Such a procedure supposes that the map content including height information is available in a digital form. The instrumentation needed for projective plotting is relatively modest and requires only a digital tracing table as it is already used to a large extend for stereo-plotting.

This procedure has proved its value especially for land use registrations based on sampling methods (cf. Fig. 1). In Switzerland, this technique is at present used for the official land use statistics and the national forest inventory. According to the same principles different tests have been made for cadastral renovation (cf. Fig. 2) and for revision of forest stand maps. The procedure has proved extremely useful whenever the original photograph or an enlargement has to be compared with the map content. However when corrections or complements have to be made it is a handicap that these corrections cannot be shown up in the same manner as the original plot, especially if lines have to be eliminated or a section of the map content has to be displaced due to imprecisions of the original map. Nevertheless this procedure has considerable advantages and it is regretable that this simple method is rarely used in connection with stereo-plotting. A special advantage of this procedure is that the documents can be easily taken into the field for verifications and further detailed studies.

4. Image injection into the optical path of a plotting instrument

The next step would be to display the map onto a monitor and inject this image into the optical path of a stereo-plotter. Such an instrument has been developped recently by INTERGRAPH, among others, and also introduced into practice. Furthermore, the Institute of Photogrammetry has done considerable research work in this direction. For the first tests, a table-computer of the type HP 9845 was used. Later on, more powerful processors were incorporated and of special interest are the tests with a working station SMAKY 8 developed by the Laboratory of Microinformatic of the Swiss Federal Institute of Technology of Lausanne. This working station is based on a Motorola 68000 processor.

The tests were made in connection with the stereo-plotter KERN PG2 (cf. Fig. 3). The Institute already had this instrument at its disposal with an instruction ocular; consequently it was rather easy to adapt the optics for image injection. The neces-

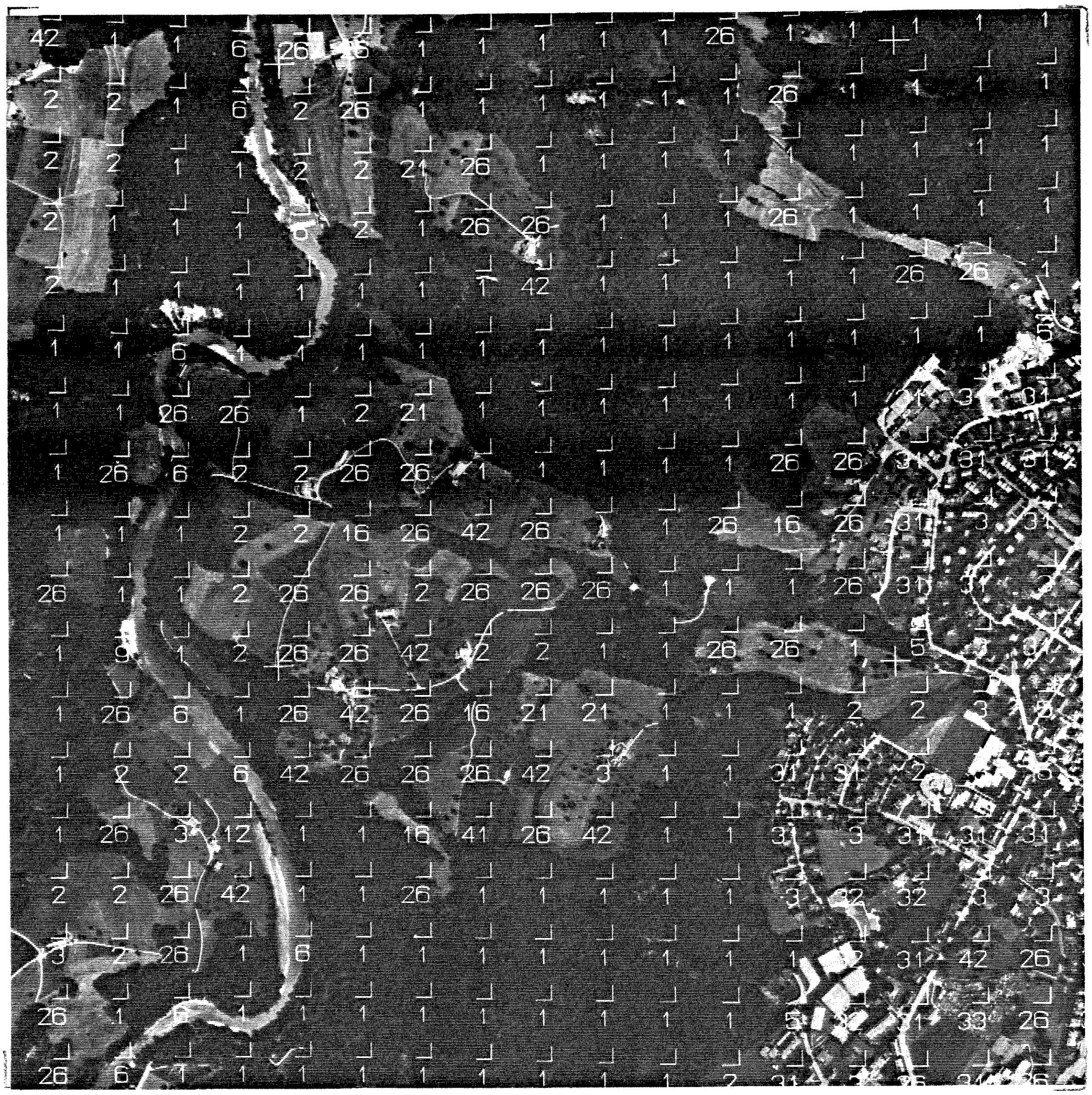

Fig. 1

Aerial photograph with superimposed land use interpretation (Photograph reproduced by courtesy of the Topographic Service of Switzerland).

Fig. 2

Superimposition of an aerial photograph with a cadastral map. The transfer was done analytically correct and deviations are purely due to errors of the map (e.g. road limit). The buildings are plotted two times, the dashed line corresponds to their base at the level of the roof (Photograph reproduced by courtesy of the Federal Directorate for Cadastral Survey, Bern).

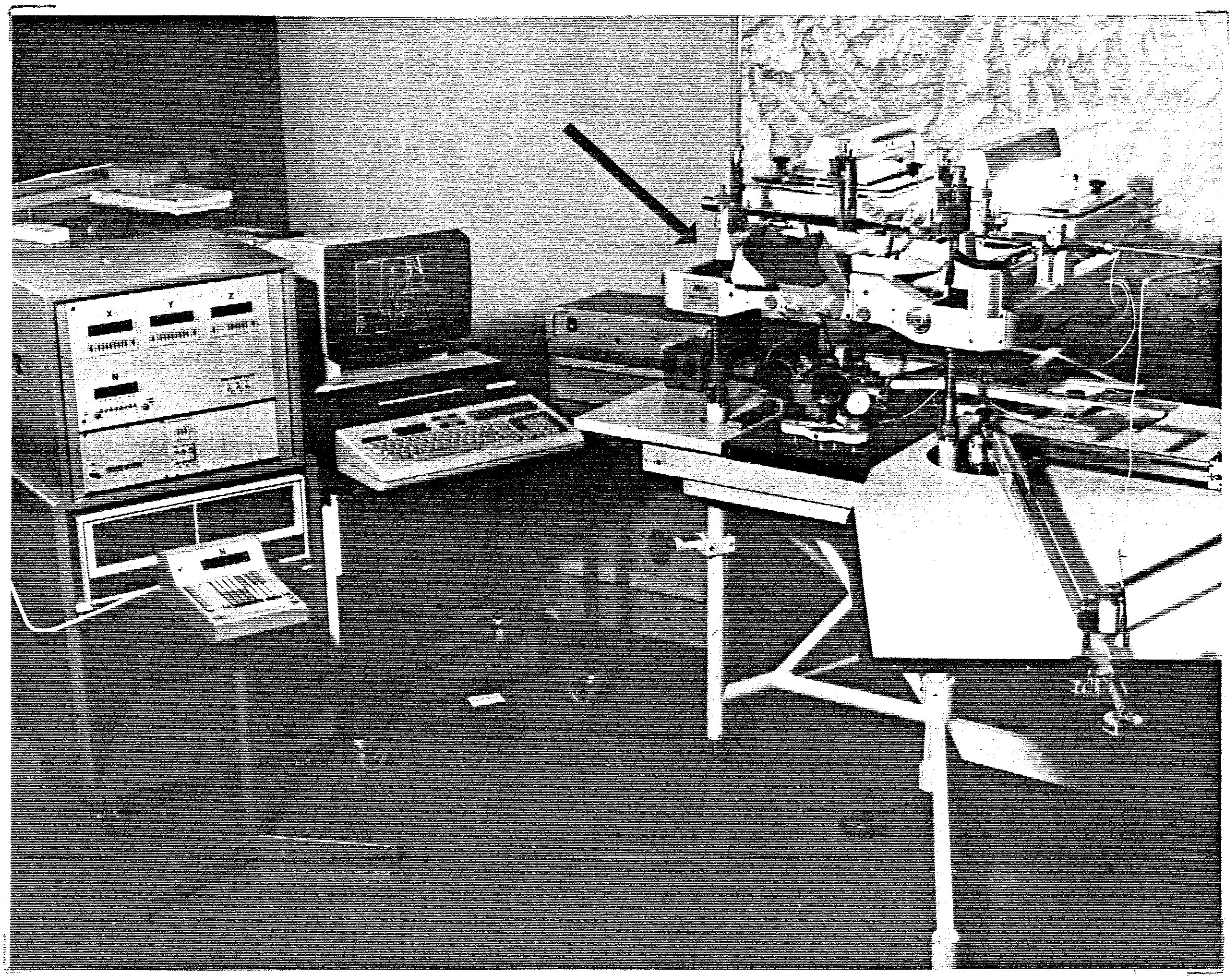

Fig. 3

Image injection of a map shown on a monitor into the oculars of a stereo plotter (Kern PG2). That image injection is realized with the help of a semi-transparent mirror and a projection lens mounted near the oculars (cf. arrow).

sary constructive adoption was effected in the Institute of Photogrammetry in collaboration with the Central workshop of the Institute of Technology. The optical components used were a prism with a semi-transparent surface and a projection lens with a focal length of 70 mm ($\varnothing$ = 30 mm); additionally a Dove-prism was incorporated in order to correct image rotations. The optics can also be orientated with the help of adjusting screws to allow for the correction of image-displacements. However, it seems more appropriate to provide the optical path with plan-parallel plates and keep the optical system fixed.

The rather bright optics allows the use of commercially available screens without especial requirements on image brightness. The injected image of the screen stood out sufficiently well against the background of the aerial photograph and required only a slight reduction of the illumination of the photographs.

However, the computation speed of the table computer HP 9845 was completely unsatisfactory. Even the use of an assembler program did not allow more than 10 image-displacements per second. Different tests have shown that frequencies of about 50 Hz should be obtained in order to give the operator the impression that the image on the screen coincides completely with the aerial photograph in the stereo-plotter during scanning movements. These high requirements are surprising if one takes into account that, for example, in movies a frequency of 18-24 Hz is considered as completely satisfactory. However, higher frequencies are necessary to assure that the two images are always in complete register. The recomputation and display of an image in a frequency of about 50 Hz requires very sophisticated electronic components. In this connection it should be taken into consideration that the average number of vectors of a map corresponding to a model section might be 100'000 vectors and even more and for the size of a model of about 23 x 14 cm a resolution in the order of 5 µm should be obtained. Simple estimations show that it is completely hopeless to treat these data as a unit and to recompute continuously the image on the screen.

The practical tests in the Institute of Photogrammetry were carried out mainly with the help of sections. Furthermore, tests were made with the injection of stereoscopic images. These tests required the use of two screens with appropriate geometrical corrections of the image.

This investigation shows that a general purpose computer is hardly appropriate to treat this huge mass of data and it seems considerably more efficient and more economic to conceive special purpose processors for the data manipulation.

5. Monitoring of aerial photographs on a screen

The preceding chapter illustrates the difficulties which arise when an image on a screen and a photographic image are compared. The adopted solution must be considered as a hybrid solution. A more straight forward solution would be to show up both images immediatly on a colour screen, as currently adopted for the treatment of remote sensing data. These simple considerations show, however, that current monitor equipment is not able to give a similar performance to that usually used in stereo-plotters. Colour monitors have normally a resolution of 450 x 550 image elements whereas the optics in stereo-plotter gives much higher performances. When analysing photographic images, one can state that observation systems with a resolution of up to 100 lines/mm should be used and that the loss of contrast should not be higher than about 10-20 % for resolutions of about 60 lines/mm. This performance is fully used when working with image enlargements of about 15-20 times and might refer to a field of view of about 1 cm. In order to obtain a resolution of about 100 lines/mm three folds of pixels would be necessary so that 300 x 300 pixels would already be necessary to represent only one square millimeter. For the field of view of one centimeter one would consequently need monitors of 3000 x 3000 pixels. Compared with modern television equipment this would mean that about 20-40 times more information has to be handled. It seems evident that in future such high performance will be available even for television but a considerable development work will be necessary until such an equipment can be used for photogrammetric plotting.

6. Conclusions

For an evaluation of the different procedures it seems important to define beforehand the aims in map production. As long as for example the cartographic production process occurs fully graphically the use of orthophotos might be quite appropriate. However when the map information is managed with the help of an information system, then the process of stereoplotting might be much more useful. In the long run the set up of integrated information systems will doubtlessly be a primary aim. Data collection should then be concentrated on the elaboration and revision of these systems. As already explained, stereo-plotters offer optimal conditions for digital data registration provided that it is possible to present the content of the data bank in a proper way together with the content of the photographic images. From this point of view, considerable importance is attached to image injection concerning an image shown up on a monitor and injected into the optical path of a photogrammetric plotter. Other alternatives for combination of graphical information and image information as orthophotos or projective deformed maps should not be obsolete under these conditions. However these procedures should be considered as an enrichment of the possibilities for information output of a land information system.