OPTICAL SUPERIMPOSITION OF STEREOMODEL AND GRAPHICAL INFORMATION AS A TOOL FOR DEM QUALITY CONTROL

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Abstract

Optical superimposition of measured DEM data or contours derived from the DEM with the stereomodel enables the operator to check these data visually with respect to completeness, correctness and to the fidelity of the terrain representation. This paper describes selective and progressive sampling - using the further developed program PROSA for computer assisted DEM data acquisition - supported by optical superimposition of the measured data with the stereomodel using the ZEISS VIDEOMAP system. Besides that this superimposition is used for a visual check of contours derived with the DEM program package HFTI. Finally the possibilities of a corresponding on-line procedure are suggested.

1. Introduction and review

At present the digital elevation model (DEM) is used not only for quite a lot of tasks in planning and mapping but have also become part of land information systems /Ebner, Fritsch, 1986/ which means that high demands are made on the DEM quality. These high demands on the DEM quality also require an accurate and comprehensive data acquisition.

Considering only methods for photogrammetric DEM data acquisition one can say that measurements arranged in grids supplemented with selectively sampled data are very common in practice. As shown in /Ebner, Reinhardt, 1984/ this combination becomes more effective if the progressive sampling method is used because it leads to the same DEM accuracy with better economy or to the same economy with better DEM accuracy compared with the measurement of complete grids. But one weak point of this kind of data acquisition is to ensure the completeness and correctness of the selective sampled data. This test is done mostly off-line by using control plots of the sampled data, which is rather inconvenient and time consuming. Furthermore a check whether the selective and progressive sampled data represents the terrain adequately can be performed also only off-line in most cases by contour plots.

In this paper the use of a system for superimposition of stereomodel and graphical information for checking DEM data will be discussed. At first the selective sampling using optical superimposition for an on-line check of the completeness and correctness of the measured data will be described. After a short description of the PROSA program for progressive sampling the data acquisition using this PROSA program supported by optical superimposition will be introduced.
Optical superimposition is used here to visualize the previously measured selective data as well as the progressively sampled data to enable the operator for an on-line check of the quality of the terrain representation. Furthermore it will be discussed how the finally reached DEM quality can be tested by superimposing contours derived from the DEM with the stereomodel. The paper concludes with a practical example and comments on the results.

2. DEM data acquisition supported by optical superimposition

In the following the ZEISS VIDEOMAP system is used to support DEM data acquisition. This system was introduced in 1984 at the ISPRS Congress in Rio de Janeiro and is used very effectively in practice for an on-line check of the recorded situation data. It is used in connection with an analytical plotter ZEISS PLANITCOMP and it consists of a HEWLETT PACKARD high resolution vector display unit and a control unit. The graphical data is displayed on the vector screen and superimposed with the left photo of the stereomodel by an optical interface. For details see /Saile, 1984/.

2.1 Measurement of selective data

Selective Sampling /Makarovic, 1984/ for DEM mainly including characteristic points, break lines, skeleton lines and cut out areas not only improves the DEM quality compared with pure progressive sampling but especially the break lines are also necessary for the performance of progressive sampling. But the measurement of the selective data using an ordinary analytical or analogue stereoplotter in practice leads to an incomplete and incorrect data set because the operator is not able to see what he has measured. Checking the selective data is performed mostly by off-line plotting which is either time consuming or by on-line plotting e.g. at a tracing table which is not very economical and also inconvenient for the operator because of continual alternating between the stereoplotter and the tracing device. This disadvantages are avoided if the measurement is supported by a system for superimposing graphical information with the stereomodel which enables the operator to carry out an on-line check of the completeness and correctness of the selective data because all measured elements are made visible to him directly at the stereomodel.

2.2 DEM data acquisition using PROSA

- Progressive sampling using PROSA

The PROSA program developed in Munich on behalf of ZEISS / Oberkochen was first presented at the Photogrammetric Week 1983 in Stuttgart / Reinhardt, 1984. The program uses the method of progressive sampling...
For progressive sampling first a basic grid is measured. Then second height differences are computed at the grid points in both directions taking into account break lines if available. If at least one second difference exceeds a pre-chosen threshold, the basic grid is locally densified to half the original mesh size. This procedure is repeated once so that the basic grid width is the quadruple of the minimum grid size. For local densification of the basic grid, the overall area is subdivided into patches of approximately eyepiece image size. Each patch is processed completely with up to two densification steps. For the measurement of heights the floating mark is prepositioned to the densification points in plan and approximately in elevation so that the operator can concentrate only on height setting. A more detailed description of the program and some experience with it are given in /Ebner, Reinhardt, 1984/.

- Specification of sampling parameters

The necessary basic grid width and threshold value for progressive sampling can be chosen by experience. But as two densification steps are used for progressive sampling the basic grid width is the quadruple of the minimum grid width, which itself can be obtained by using a more objective terrain analysis procedure. Various concepts for the estimation of the minimum grid width according to a required accuracy using terrain profiles are given in the literature /e.g. Tempfli, 1982; Kraus, 1984; Fritsch, 1985/. For this paper a program was used which is based on a concept suggested by /Rüdenauer, 1980/ This program consists of a successive thinning out of a dense terrain profile where at a distinct thinning out step every n-th point (n= 2... N-1, N = number of profile points) of the profile is used for linear interpolation of the heights of the other profile points, also taking into account the break points of the profile. Then the differences of the interpolated and the original heights at these other points are calculated. At the moment the decision which point spacing is suitable for the actual project is done manually by the operator using histograms and the RMS value of the differences for different thinning out steps. An automatically solution of the problem is still in preparation.

- Progressive sampling using PROSA supplemented by selective sampling

Although the use of the progressive sampling method leads to a point density and distribution which is matched to the roughness of the terrain there is still a -in general small - risk that there are terrain features left which are not represented in the measured...
data set. This may be caused by an incorrect choice of the sampling parameters as well as by an incomplete capturing of the selective data or more simple by terrain features lying completely inside of a grid mesh. All such errors can be avoided if the operator is able to see the planimetry of all measured data directly at the stereomodel. For this reason the PROSA program has been extended in such a way that at each patch the selective data already measured are first superimposed with the stereomodel. After that all progressively sampled points are also visualized at the stereomodel. This enables the operator to assess the quality of the data acquisition or in other words the fidelity of the terrain representation visually. Furthermore, he can interactively influence the program controlled data acquisition, if the data acquisition is not adequate to the terrain roughness. For example he can suppress required point measurements, he can supplement the PROSA points by selectively captured points or he can switch to pure selective point measurement at regions where this is more efficient.

3. Superimposition of contours with the stereomodel

Besides the check of the measured DEM-data optical superimposition of contours derived from the DEM with the stereomodel allows for a quality check of the generated DEM. Although these contours are superimposed only to the left photo superimposition enables the operator to check the form of the contours by comparing them with the local shape of the terrain. This means one has to check if terrain forms like ridges, drainages or others are represented correctly by the contours. Of course it is necessary for this test that the contour program usually is able to process various kind of data included in the DEM like break lines, skeleton lines and local minima or maxima in a correct manner. Besides the form also the density of the contours can be compared with the stereomodel and that means the operator can check the curvature of the DEM as well as the slope. And even the heights of DEM points can be tested by some height settings on arbitrarily selected points of contour lines and a comparison between the measured height and the nominal height of the contour line. A comprehensive but time consuming test can be performed by directly re-drawing the contours at some sections of the area. If the check brings out significant discrepancies of the contours the DEM has to be revised. At most cases the incorrect contours might be improved by additional measurements of single points or line elements. In this case the DEM has to be at least partly regenerated and also the contours (Östman, 1986). It is obvious that one should try to avoid such re-measurements if possible. And this means data acquisition should be performed as comprehensively as necessary for a correct representation of the terrain. One suitable tool to achieve this is to support data capturing by optical superimposition as suggested above.
4. A practical example

The model “Sinngrund” was evaluated aiming at the generation of a high quality DEM and the subsequent derivation of contours. A contour interval of 2.0 m seemed to be suitable in this case. The material consists of one stereomodel, photoscale ~ 1:15 000, pictures taken with a ZEISS RMK 15/23. For the establishment of the DEM a test area of 960 m × 1680 m² was chosen.

- Measurement of selective data

Within the whole DEM area 1225 points along break and skeleton lines respectively were measured at the PLANICOMP C100 supported by the VIDEOMAP system. Because all measured line elements were made visible on-line to the operator an off-line data checking could be avoided.

- Specification of sampling parameters

For this reason three terrain profiles were measured with a point distance of 5.0 m and additionally the break points of these profiles were recorded. These measurements had been used to perform the thinning out procedure described above. For a point distance of 15.0 m the mean RMS value of the differences in height at the checkpoints of all profiles was about 0.5 m and the number of differences greater than 1.0 m (one half of the contour interval) was lesser than 5% of the checkpoints. Therefore a point distance of 15.0 m seemed to be adequate to the derivation of 2.0 m contours. Consequently the basic grid width for progressive sampling was set at 60.0 m and the threshold value was set at 5.0 m.

- Progressive sampling supplemented by selective sampling

Progressive sampling was performed also at the PLANICOMP C100 using the PROSA program supported by VIDEOMAP. Each patch was processed in a way that at first the previously measured selective data were superimposed with the stereomodel and after that also each progressive sampling point were made visible for the operator. It has shown that the visualized graphical information was used mainly after the progressive sampling procedure was finished to check whether the data acquisition was representing the terrain adequate or had to be supplemented by selectively measured points. Finally there were 2245 points sampled at the whole area including only about 2% supplementary measured single points. In some sections of the area - mainly covered by streets with artificial slopes - progressive sampling was suppressed and selective sampling was chosen. To sum up the experiences gained by this practical example in this special case - with suitable chosen sampling parameters how it seemed - the operator had to supplement the computer assisted data acquisition only a few times. But it can be said, that the visualization of the measured data and the corresponding possible check of them increases the operator’s confidence in the data acquisition considerably and makes the procedure more interesting for him.
- Superimposition of contours with the stereomodel

Using the DEM data described a 15 m raster DEM (7345 points) was generated using the HIFI program package /Ebner et al, 1980; Ebner, Reiß, 1984/. From this DEM contours with 2 m and 5 m contour interval were derived also by using HIFI. Because the very dense planimetry of the 2 m contour lines affected stereoscopically viewing the stereomodel the 5 m contour lines were used for a check of the DEM quality also by using VIDEOMAP. This test was performed in a way that at first terrain forms had been checked as to the suitability of their representation by the contours. After that a direct re-drawing of the contours was performed at some regions, especially where no typical terrain forms - e.g. at rather flat terrain areas - could be recognized. The result was that the simultaneous inspection of the stereomodel and the contours showed very good accordance of both. Even the direct re-drawing of the contours resulted only in minor differences such as normally occur when measurement are retaken. This high quality of the contours was not surprising because of the complete, on-line checked DEM data.

Figure 1 shows an example of contours superimposed with the stereomodel. It can be stereoscopically viewed by using a lense stereoscope.

Figure 1: Contours superimposed with the stereomodel
5. Conclusion

The example presented has shown that optical superimposition can be successfully used for an on-line check of the completeness and correctness of the selectively measured DEM data. Furthermore the quality of the complete data acquisition can be checked directly during and after PROSA measurement by comparing the measured DEM data with the stereomodel. The completeness and correctness of the data set measured selectively and using PROSA both supported by VIDEOMAP has been proved by the high quality of the contours derived from these data. It also could be shown that the VIDEOMAP system for optical superimposition of graphical information with the stereomodel can be used principally for a quality assessment of a DEM by inspecting the derived contours superimposed with the stereomodel.

This check of contours gains in effectiveness if it is performed directly after data capturing as also suggested in /Pape, 1986/. But to arrive at such an on-line procedure - including on-line DEM generation and derivation of contours - there are still more investigations necessary which improve the algorithms for DEM interpolation according to computing times. Furthermore suitable algorithms are needed for an updating of DEM and contours if the check of the contours results in the terrain representation not being sufficient and DEM and contours having to be improved.

Such an on-line procedure of course can only be performed at limited areas analogous to the patchwise processing of progressive sampling. This means that at a later stage DEM and contours are generated on-line after measurement of each patch. Then the operator can inspect the contours superimposed with the stereomodel and if necessary subsequent improvement of DEM and contours follows.

First estimations have shown that the generation of a DEM and the derivation of contours for a patch takes about 30 sec. using the HIFI program package running on a Hewlett Packard HP 900 A minicomputer. On the one hand there are investigations running which will speed up the DEM interpolation by Finite Elements considerable /Ebner, Fritsch, HÜSCHLER, 1986/ and on the other hand the operator can easily put up with a delay of 30 sec. if in return he gets contours superimposed with the stereomodel directly after measurement for it.
REFERENCES


Abstract: 85% of Austria is covered by a digital terrain model with the point distance of 76 to 120 meters. The paper presents an overview of the method and software applied to archive the data. Terrain elevations are stored on sequential mass storage devices managed by an on-line, direct access information system. The information system stores further readily available information on extensive files (such as the files for aerial photography for projects: triangulation points, and others). Information may be processed and specified by any combination of tables and maps. Data can be displayed in different forms: contour lines, shaded relief, perspective views, orthophotos, and so on. Intermediate Webinput files are equal to input data that has recently been prepared and processed.