EXTENSION OF STUTTGART CONTOUR PROGRAM TO TREATING TERRAIN BREAK-LINES

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During the last three years a program system for processing of digital height information has been developed at the Institute for Photogrammetry of the Stuttgart University by W. Stanger. This program, which was developed for large size computers starts with randomly distributed terrain points and interpolates the heights of a rectangular grid of high density. From this "digital height model" (DHM) the contour-lines are computed and stored on a magnetic tape for the subsequent automated plotting.

By the present program the terrain breaks are only considered to some extent. Therefore we have been working at an extended version. In this lecture I want to present the first results of our endeavours.

The structure of the old version has been published several times |1|, |2|, |3|. For a better comprehension of the extended version the most important steps of the old program shall be repeated.

For computing the grid heights the map sheet is divided in rectangular computing units (figure 1). In order to avoid gaps additional overlapping zones are used for the interpolation of the grid heights in the computing unit itself. The computing unit is given such a size, that about 70 reference points are situated in each gross computing unit (= computing unit + overlapping zone).

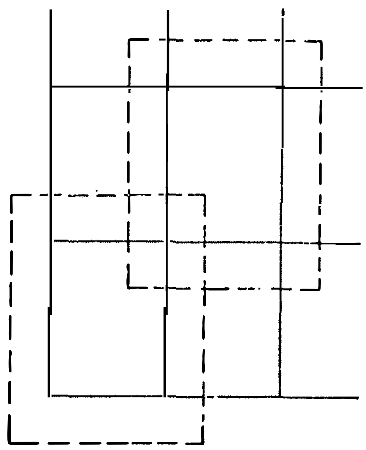

figure 1

Through these points an approximating polynomial surface of the first or the second order is fitted (figure 2). The remaining height-differences between the terrain and the polynomial surface are the reference values for the now following computation of the grid heights.

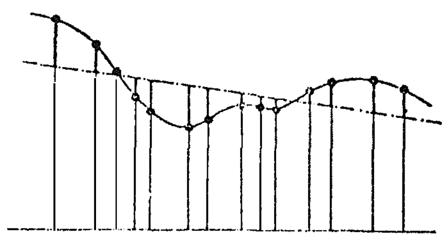

figure 2

The interpolation uses the method of the linear least-squares interpolation (= linear prediction) |4|, |5|. For this statistical interpolation-method we must know the correlation (covariance) of the heights of any two points P_i and P_k (figure 3). In our program we assume that the covariance is only a function of the distance d between points. That means that in every interpolation area (= computing unit) homogenous and isotropic statistical conditions are presumed (independent of location and direction).

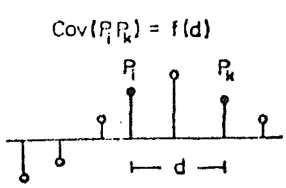

figure 3

The magnitudes of the covariances can be taken from a covariance function (generally a Gaussian function is used, see figure 4).

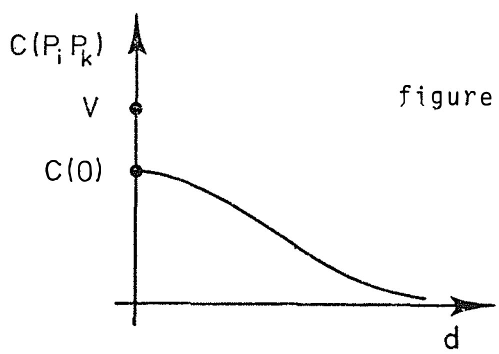

figure 4

By means of the above mentioned method of the linear least-squares interpolation the heights of the rectangular high density grid are produced for each computing unit (figure 5).

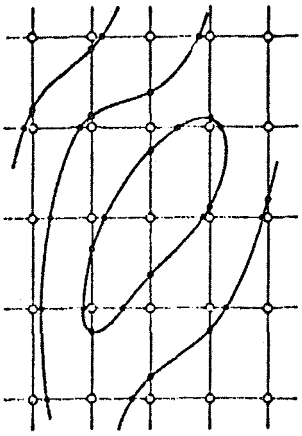

figure 5

The values of the polynomial surface are added accordingly. The resulting grid heights are arranged in the form of profiles over the entire map sheet and stored on a magnetic tape. This digital height model is the input for the interpolation of the contour lines. Contour points are computed between the grid points by linear interpolation. The points are sorted along the contours and stored accordingly. Later, during plotting, the automatic plotting table will connect the points by curves of third order.

We have been rather successful in computing and drawing quite a number of map sheets with this program. Our automatically produced contour lines are of about the same accuracy as the conventional contours, as various analyses proved. Figures 6 and 7 are to demonstrate the cartographic quality of our results.

Figure 6 shows a section of a contour map at a scale of 1 : 24 000. The given data for the whole map sheet which is about seven times the size of figure 6 are 12 000 reference points produced by photogrammetric profiling. 133 700 grid points and 153 000 contour points were computed.

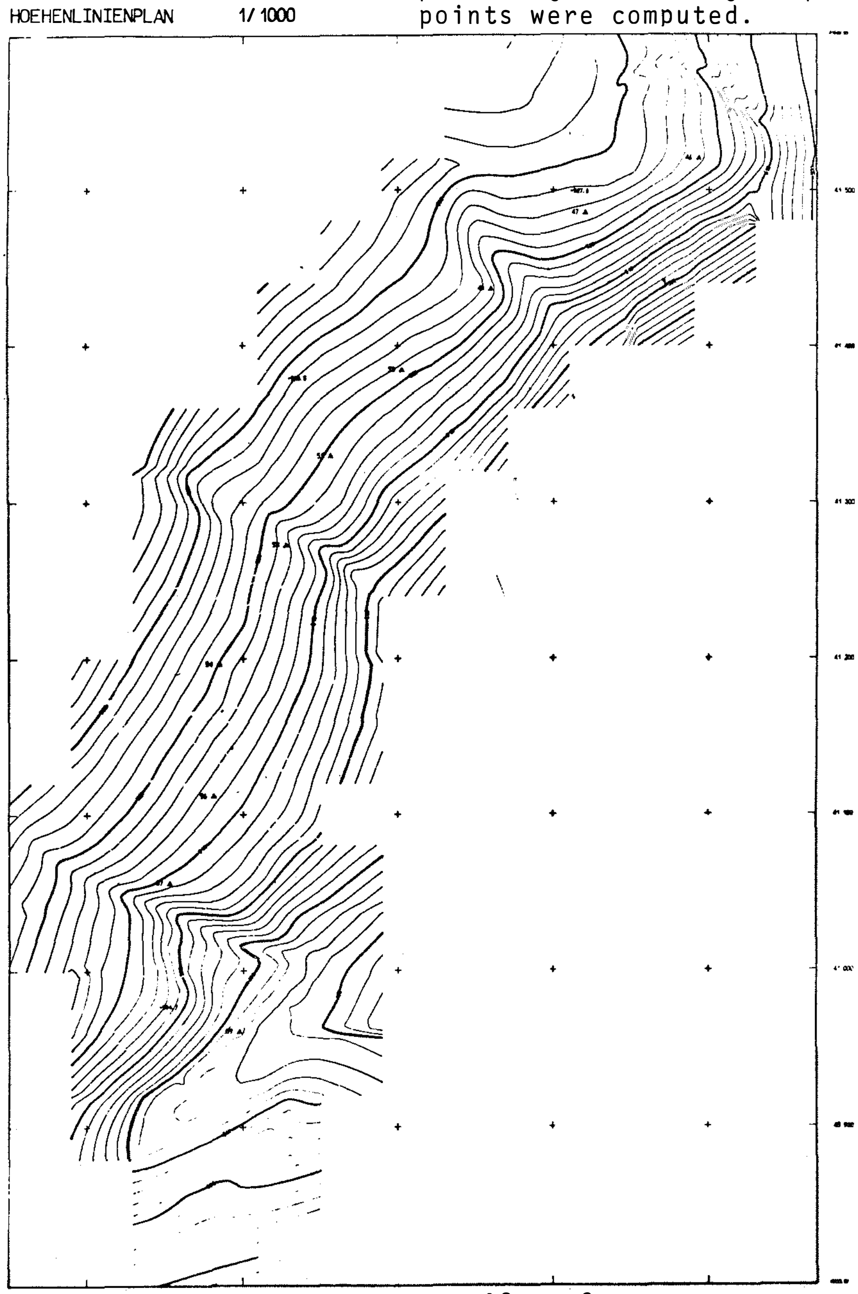

figure 7

Figure 7 is an application for road construction (scale 1 : 1000). The input coordinates came from about 400 tacheometrically measured points. This example shows some units in which no contours were computed because of too low density of given points.

Both examples demonstrate the standard of contours reached by the present version of the program. They also show where improvements ought to be made, if highest cartographic demands are to be satisfied: in the latter example several erosion features can be seen, appearing somewhat smoothed out, although sequences of points were measured along the lines. Another example is to demonstrate better that our standard program can not yet meet all demands in a complicated area.

Figure 8 is a section from a "Deutsche Grundkarte" at the scale of 1 : 5000. The critical areas are the escarpments represented by linear hachures. In collecting the data by photogrammetric measurement, reference points were recorded along the lower and upper breaklines.

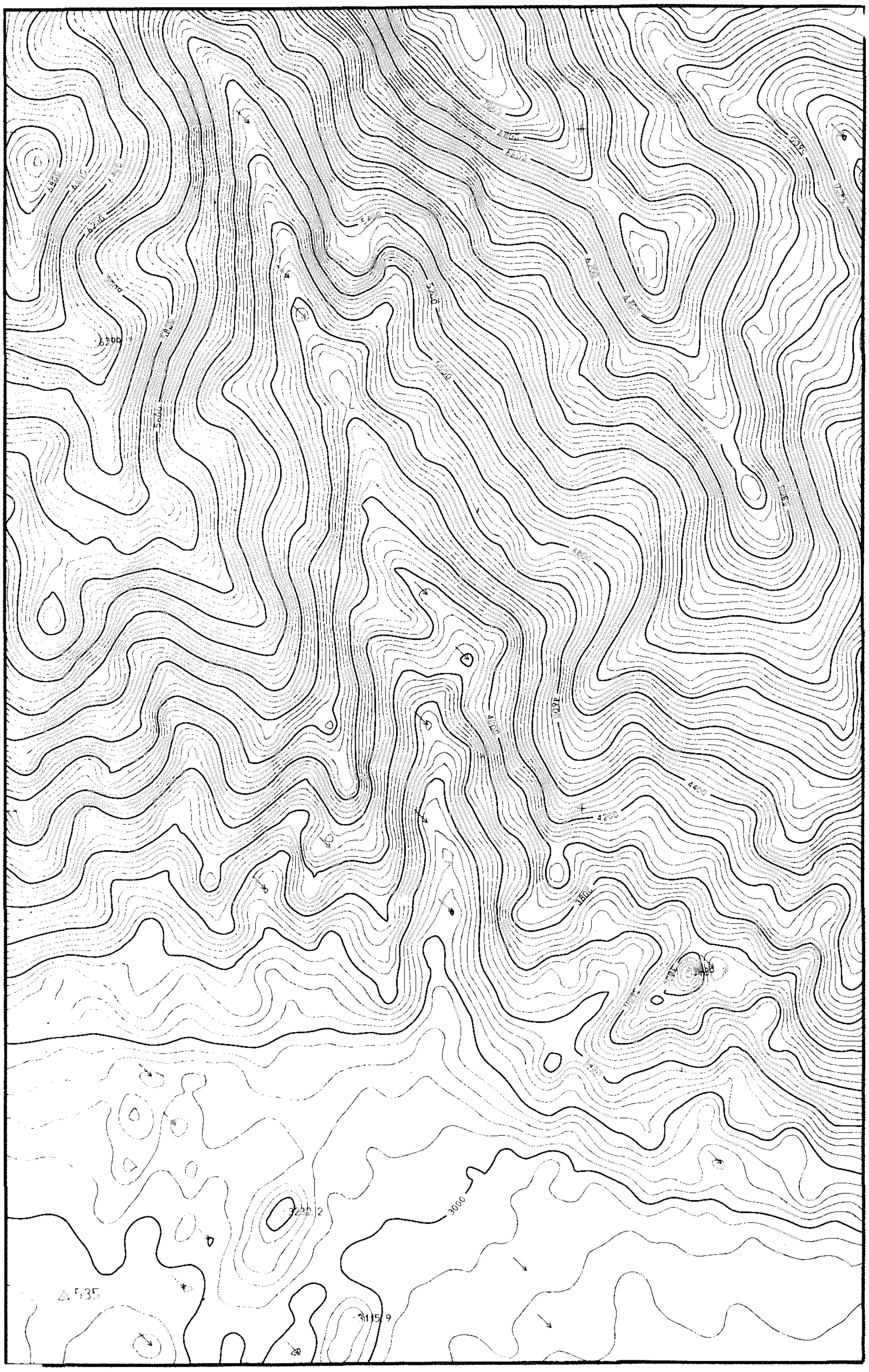

figure 6

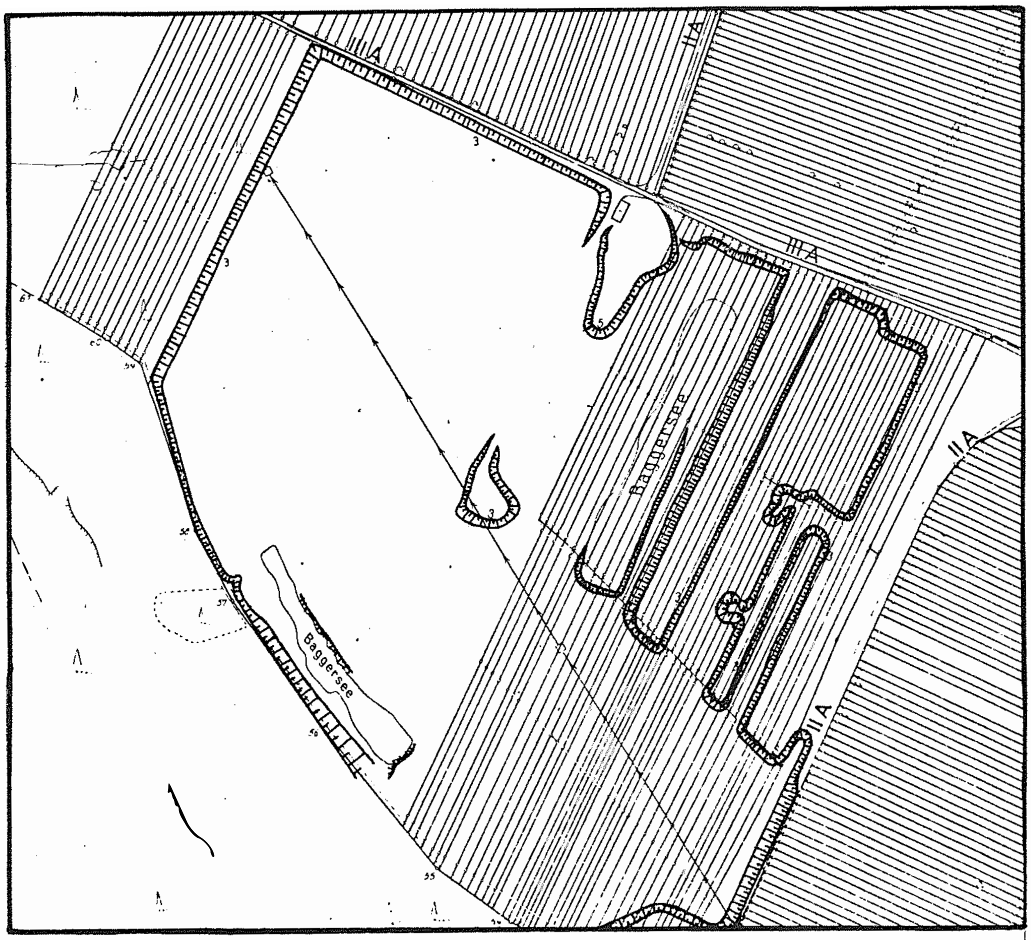

figure 8

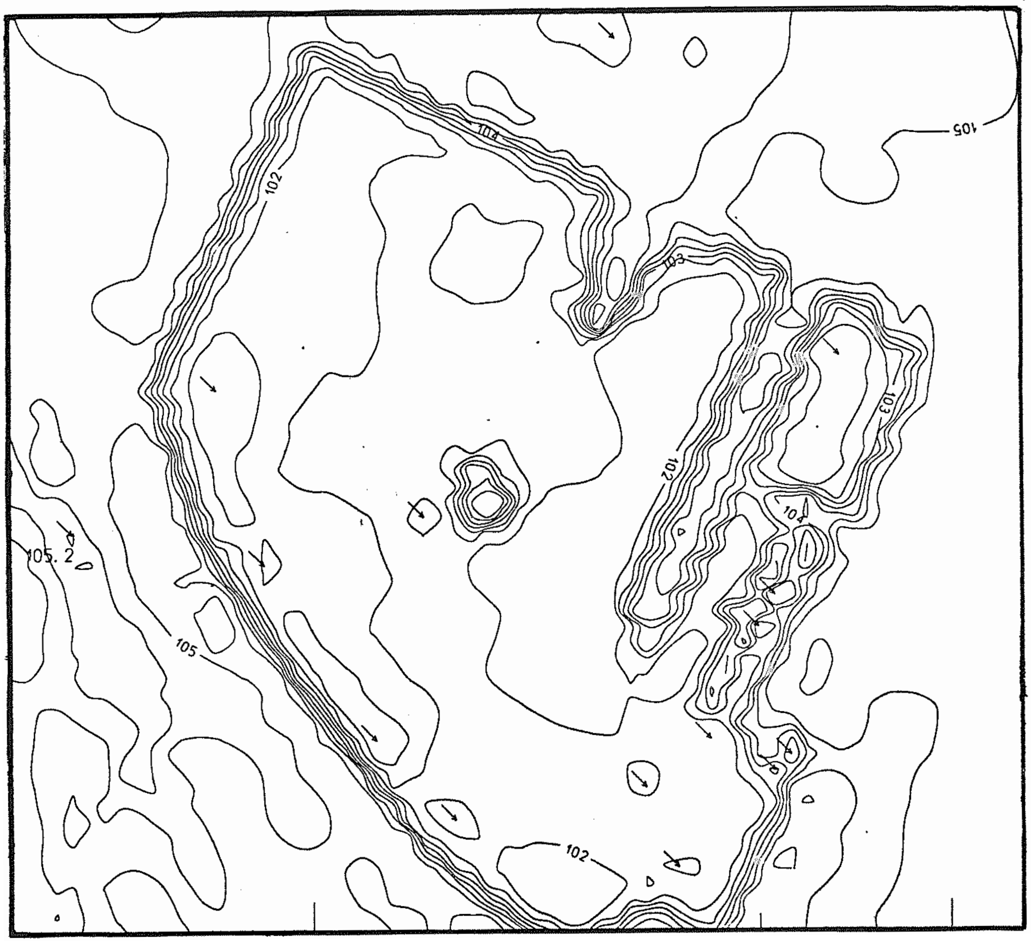

figure 9

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The contours resulting from the standard program version are not satisfactory in the slope-areas (figure 9). The interpolation, based on a Gaussian curve as a covariance function, does not accomodate sufficiently break-lines in the terrain surface. Therefore the slope discontinuities are smoothened out. In addition it is evident that the points on the break lines are used as separate points without enforcing the edge conditions. As a result the contours appear oscillating.

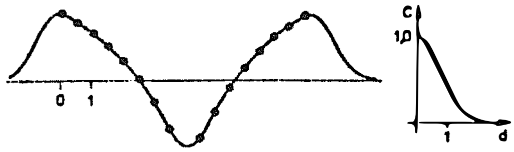

figure 10

In order to avoid such difficulties we expanded the standard contour program. The main alteration refers to the linear least-squares interpolation, according to a proposal of K. Kraus, Vienna, who designed originally the Stuttgart Contour Program |6|. The standard program version smoothenes out breaks, see figure 10 which represents a simulated vertical profile.

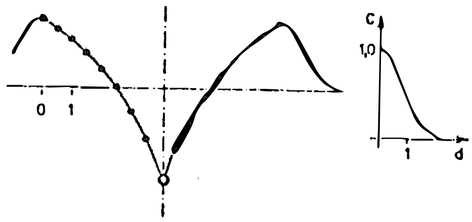

figure 11

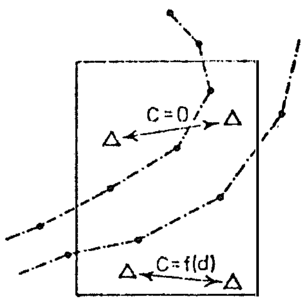

figure 12

The reason is that the covariance is treated only as a function of the distance d of any two points. In this example, however, the covariance depends on the location: two points on different sides of the break are less or even not at all correlated in comparison with two points on the same side.

Therefore in the well known equation of the linear prediction covariances between points which are separated by a break-line are set to zero (figure 11). In this way the inhomogenity is taken into consideration and the smoothing of the break is prevented.

In the two-dimensional case (figure 12) the break-lines subdivide our computing units into separate regions. Between points from different regions the covariance is set to zero. Within a region the covariance is, as before, a function of the distance d.

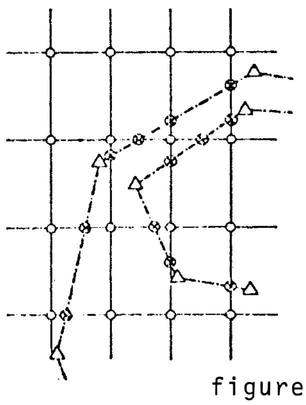

figure 13

According to this principle we interpolate the heights of the grid points (figure 13). However, we don't want to drop the geomorphological information given by the break-lines. So the density of points on the break-lines is increased by interpolating the intersections of these lines and the grid. The condensed point series of the break-lines are stored on the magnetic-tape directly after the grid heights. In this way the interpolation adheres very strongly and directly to the geomorphological features, therefore a grid with wide meshes is sufficient for the DHM.

The contour points are usually computed by linear interpolation between two neighboured grid heights (as it was done in the former program). In addition, break-lines intersecting the grid meshes are taken into account accordingly (figure 14).

Also contour points are interpolated on the break-lines.

The program has also been enlarged in that part which sorts the interpolated points by contour-lines. When a break-line is reached, the contour-line is interrupted, then restarted at the same point. Thus the plotter will produce the intended break in the contour.

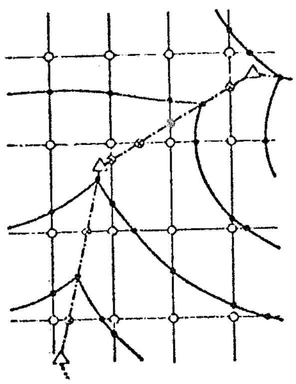

figure 14

During the last few weeks the first complete map sheet was computed with this new program. The data of the tacheometric survey, the result of which is shown in figure 7, were used once more. In figure 15 the new digital height model of one computing unit is presented (full lines = grid lines, dashed lines = break-lines). The interpolated surface clearly shows the required break.

Figure 16 shows a section of the map sheet composed of four computing units. The contour-lines break at the edges of the ravine as they ought to.

In figure 17 this new result is compared with the result of the standard contour interpolation in which the edges were disregarded (dashed lines).

Figures 18 and 19 show another section of the map sheet and the comparison with the standard interpolation.

The results of the first experiment prove that the extended program can properly present difficult geomorphological features. A striking increase of the quality of the computed contours is evident. Naturally the refined method requires slightly increased computing times.

In the following months the program will be completed and optimized.

It is felt that it will constitute a useful tool for the automatic production of contour maps of heigh cartographic quality.

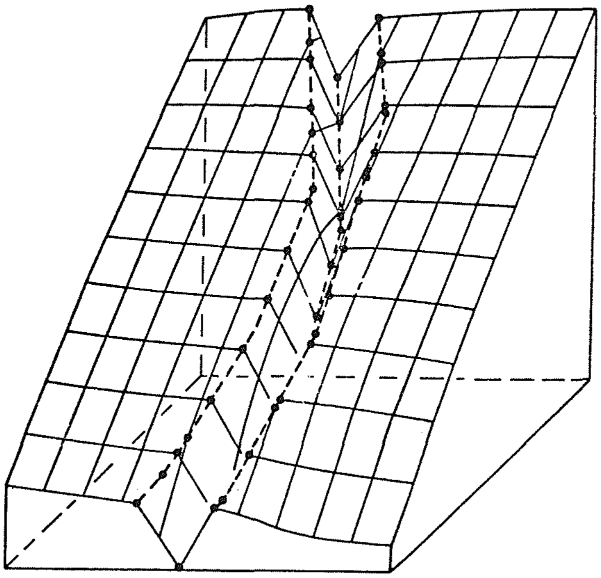

figure 15

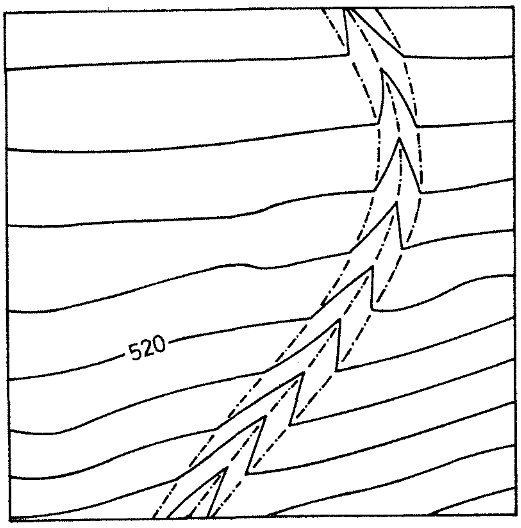

figure 16

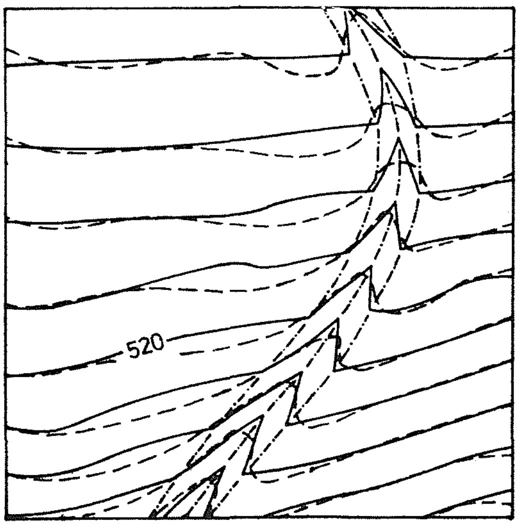

figure 17

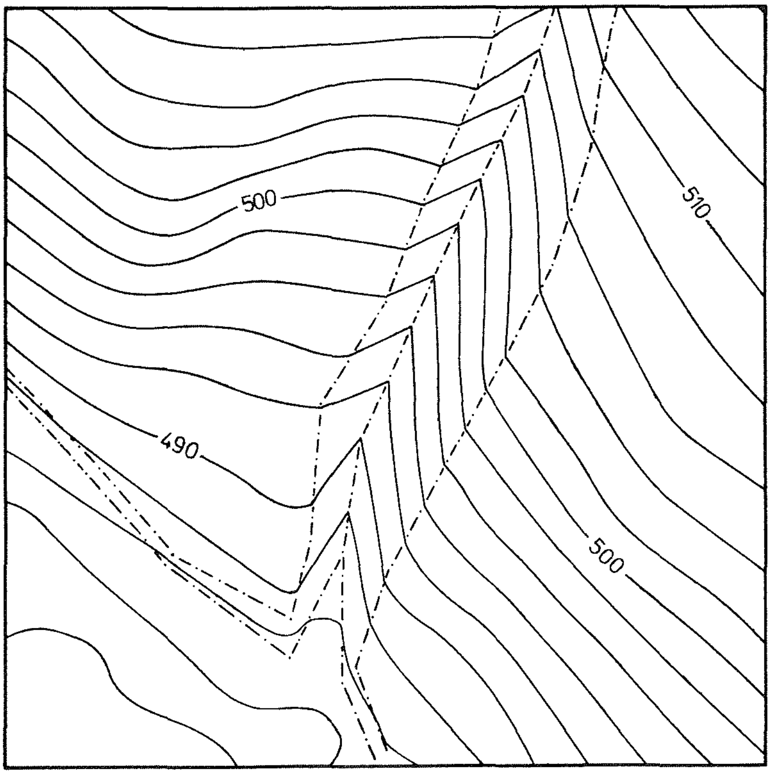

figure 18

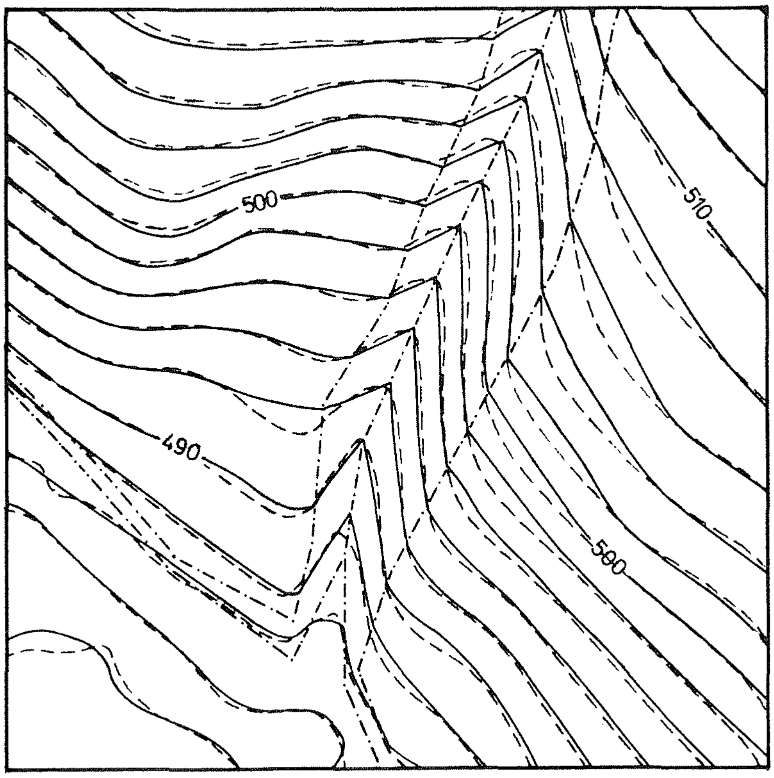

figure 19

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