The smoothed coordinates of the point $\bar{P}_i$ are then found from

$$\bar{x}_i = \frac{p_{i-1}\, x_{i-1} + x_i + p_{i+1}\, x_{i+1}}{1 + p_{i-1} + p_{i+1}} \qquad (5)$$

The smoothing effect can be influenced by varying the constant K.

3.4 Interpolation of intermediate points on contour lines

As a rule, the internal curve interpolator of an automatic plotting machine is not particularly well suited to contour interpolation. That is why the DZT 90x120 has no such internal curve interpolator. Curves have to be interpolated by the control data computing program and executed by the plotting table in the TRACK mode. In that mode the plotting table reads about 10 supporting points per second; these points should be spaced at between 0.2 and 10 mm. That way, the plotting speed can be varied largely as a function of line curvature.

3.4.1 Basic principle

The interpolation program for the densification of the supporting points of a contour reduces the point sequence P_i (x_i, y_i) into two parameter functions $x = x(t)$ and $y = y(t)$, with the chord length s being introduced as a parameter (Fig. 2). The gradient of the tangent at point P_i is established so that the tangent runs parallel to the straight line joining the two neighbouring points.

$$\dot{x}_i = \frac{x_{i+1} - x_{i-1}}{s_{i-1} + s_i} \qquad (6)$$

At the ends of a non-closed contour,

$$\dot{x}_1 = \frac{2\,(x_2 - x_1)}{s_1} + \frac{x_1 - x_3}{s_1 + s_2} \qquad (7)$$

The tangent at point P_i and the value x_i, together with the tangent at point P_{i+1} and the value x_{i+1} define a third-degree polynomial (eq. 8), which is employed for the interpolation of further supporting points between points P_i and P_{i+1}.

$$x = a_0 + a_1 t + a_2 t^2 + a_3 t^3 \qquad (8)$$

The coefficients of the polynomial (8) are

$$a_0 = x_i$$

$$a_1 = \dot{x}_i$$

$$a_2 = - \frac{2\,\dot{x}_i + \dot{x}_{i+1}}{s_i} - \frac{3(x_i - x_{i+1})}{s_i^{\,2}} \qquad (9)$$

$$a_3 = \frac{\dot{x}_i + \dot{x}_{i+1}}{s_i^{\,2}} + \frac{2(x_i - x_{i+1})}{s_i^{\,3}}$$

Analogous formulas apply to the parameter function $y = y(t)$. The interpolator computes the coordinates x_j and y_j of a value lying between the given supporting points.

3.4.2 Form factor

The tangent to the curve at point P_i is not changed in the x, y coordinate system if $\dot{x}_i$ and $\dot{y}_i$ are multiplied by the same constant F_i. This property can be utilized to influence the form of the curves. Given a suitable distribution of supporting points, the constant F can be selected so as to have the maximum curvature lying either at the supporting points or between them, and to have the curves more or less slender or bulged. In the CONT program, F = 1.2, with the effect that optimum approximation to a true circle is achieved if 6 supporting points are equally distributed on a circle (Fig. 3). The spacing of these points should therefore about correspond to the desired radius of curvature. Accordingly, the definition of the tangent differs from the representation in Fig. 2.

Supporting points of a contour line interpolated in a rectangular grid do not coincide with distinguished points at which the contour shows maximum or minimum curvature. The contour curvature itself is unknown first. It is therefore possible to introduce a variable form factor F. F = 0 leads to a linear interpolation. It is possible to determine the factor F_i as a function of the angular change $\ddot{x}_i$ and $\ddot{y}_i$ of the chord polygon at point P_i

$$\ddot{x}_i = \frac{x_i}{s_{i-1} + s_i} - \frac{s_{i-1}\,x_{i+1} + s_i x_{i-1}}{(s_{i-1} + s_i)^2} \qquad (10)$$

$$F_i = 1 + 50\,(\ddot{x}_i^{\,2} + \ddot{y}_i^{\,2})^2 \qquad (11)$$

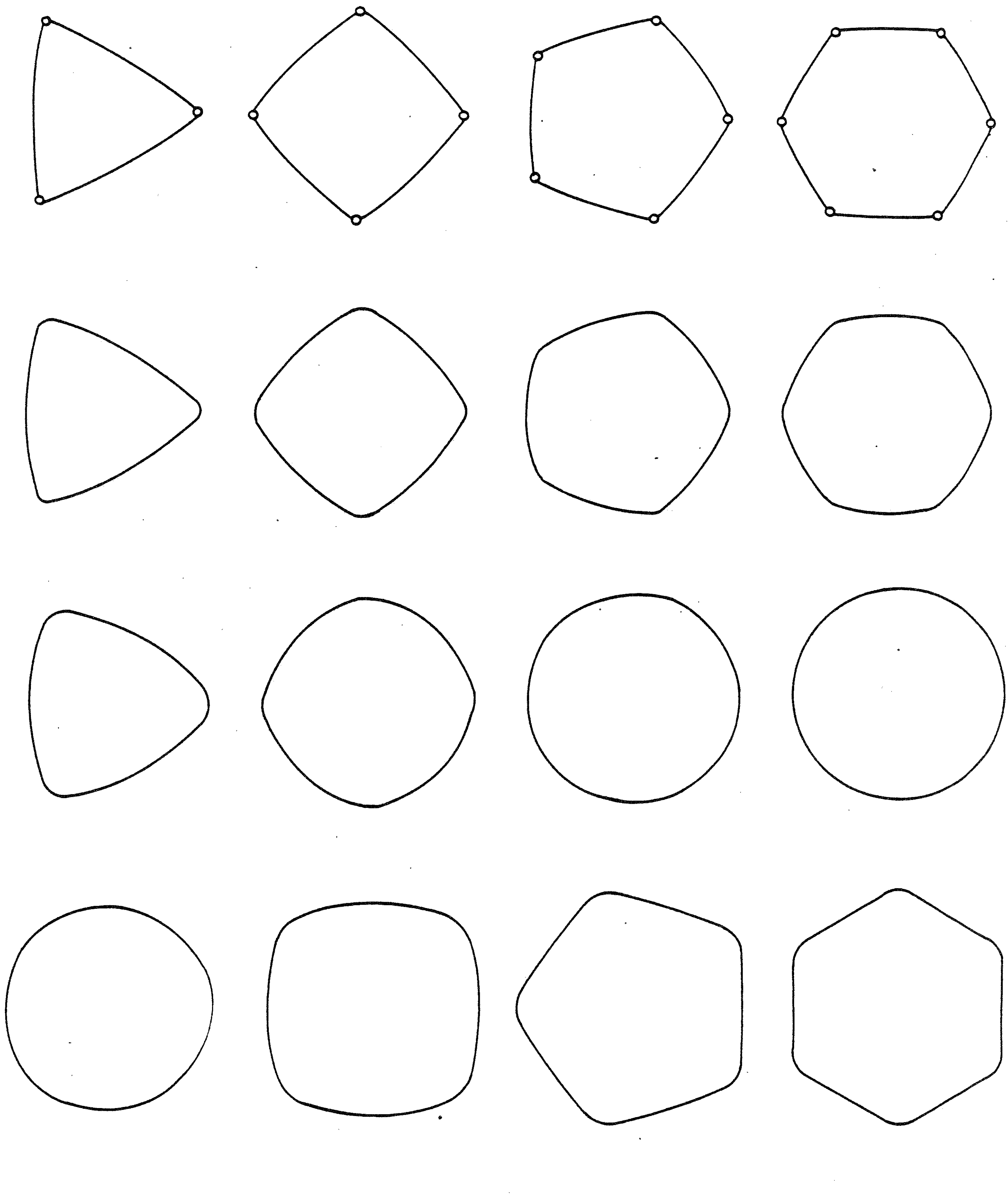

Fig. 3 Influence of form factor F on curves interpolated with 3 to 6 nodes equally spaced on a circle. F = 0.4, 0.7 , 1.2 and 2.5 (top to bottom)

3.4.3 Interpolation interval

To optimize the plotting speed it is necessary to vary the interval Δt with curvature. In the CONT program, the interval is established from the 2nd derivatives of the two parameter functions at points P_i and P_{i+1}. For estimating an optimum interval, then, the first derivative is neglected.

$$\Delta t = \sqrt{\frac{A}{|a_3| + |b_3| + |a_3+3a_4s_i| + |b_3+3b_4s_i|}} \qquad (12)$$

This is followed by a correction so as to have

$$s_i = n\Delta t_i \qquad (n = \text{integer}) \qquad (13)$$

Constant A in eq. (10) is set at 0.5 mm^2 in the program. Increasing the constant will lead to greater intervals and, thus, faster plotting.

4. Example

Fig. 4 shows a section of a contour map at a scale of 1:10,000, plotted automatically with the DZT 90x120 Digital Plotting Table. The initial data were logged during on-line differential rectification with the TOPOCART-D/ORTHOPHOT-E.

References

[1] Kraus, K.: Prädiktion und Filterung mit zwei verschiedenen Stützpunktgruppen. ZfV 98 (1973) 4, 146 - 153

[2] Kusch, M.: OFF-DE 78 - ein Programmpaket für die Off-line Differentialentzerrung. Vermessungstechnik 28 (1980) 3, 80 - 82

[3] Marckwardt, W.: Digital Filtering of Profile Data. Photogrammetria 34 (1978), 111 - 117

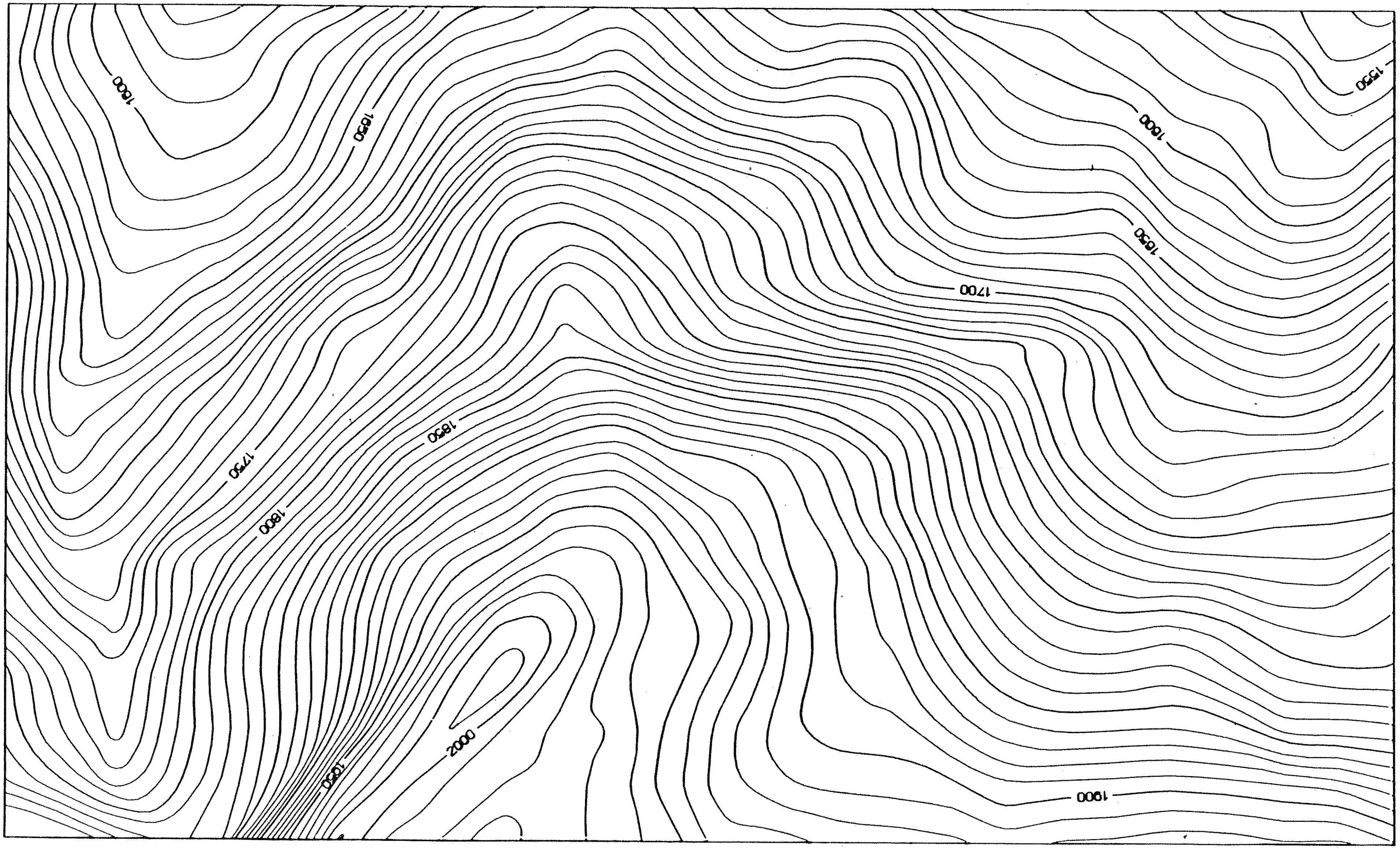

Fig. 4   Test plot of a 1:10,000 contour map

ON-LINE ANALYTICAL AERIAL TRIANGULATION USING "POLIFIM" SYSTEM

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Zusammenfassung
POLIFEM ist ein rechnerunterstütztes System, das aus höchstens 8 Datenerfassungsstationen und einem INDEPENDENT-100 F Kleinrechner, oder einem ähnlichen, besteht.
Eine Datenerfassungsstation umfasst einen Stecometer, Coordimeter E/F/G, ein dem Typ des Coordimeters entsprechendes Interface und ein alphanumerisches Display. Die Dateien mit den geprüften Ergebnissen der Messungen, die demselben Aerotriangulationsblock angehören und von verschiedenen Operateuren in verschiedenen Tagen durchgeführt wurden, werden vereint. Es wird die Streifen- oder Blockausgleichung der Aerotriangulation, an Hand der Methode der unabhängigen Modelle, durchgeführt. Die Aerotriangulationsverarbeitung kann von jedem Operateur für die von ihm erzeugten Dateien oder von dem Operateur an der Rechenanlage für sämtliche Dateien, die zu dem selben Block gehören, gestartet werden.

Aerial triangulation methods - using independent models or bundels - have compelled recognition regarding either their accuracy or efficiency, when ground control points required by the photogrammetric plotting had been determined. Nowadays, nobody doubts about the possibilities these methods can afford.
In spite of all recognized advantages, the following drawbacks are experienced during the aerial triangulation process:

- a break between measurements and computations is detected during the technological process, many a time being accompanied by the data support conversion;
- adjustment computations are not made within the photogrammetric divisions, by photogrammetrists;
- gross data errors and blunder detection and elimination, require successive runnings and the proper decision approvals need the photogrammetrist participications.

These troubles can be removed by establishing analytical photogrammetric plotting centres, which are assisted by proper efficiency minicomputers.
Today, many photogrammetric units have analogical stereoplotting equipment, Comparators and Stereocomparators provided with automatic registering devices at their disposal, which will be used a pretty long while, their replacements being conditioned by updating possibilities.
Connection of all these devices with interfaces proper to the automatic coordinate registering systems in a minicomputer ensuring the collected photogrammetric data acquisition, validation and processing proves to be an economic and favourable solution. Within these concerns, POLIFEM systems were worked out by The Institute of the Computation Technics and the photogrammetric units in Bucharest, coupling one to eight data stations to an I-102 F or CORAL 4011 minicomputer. A data station is composed of a Stereometrograph or a Stecometer with a E,F or G - type Coordimeter, made by Zeiss Jena, a DAF 2010 alphanumerical display and an interface designed differently for each Coordimeter.
System allows data acquisition, point by point, for aerial

triangulation simultaneously from 8 stations, each station being in an independent conversational relation with the computer through the display, in time sharing regime. These hardware facilities have brought about a strong software development, oriented to an on-line aerial triangulation process. System running is directed by CPD (primary photogrammetric data acquisition) programme package, ensuring maximum 5 aerial triangulation blocks approaches simultaneously, which features are introduced as answers to the system requests at the beginning of the data acquisition process. Within the measurement conversational process, the station operator has the following main system functions at his disposal:

- Work definition by means of which data related to the station are communicated to the system, operator, photogrammetric material features, work condition,a.s.o.;
- primary data input, their affiliation definition included, their proper acquisition, the compulsory interior and relative orientation validation, poit numbering in the strip, the successive model connections, optional absolute orientation validation and data recording in the established file;
- primary data file editing, which the station operator has created, making point identification, some data change, deletion or replacement;
- consulting of the established file contents, which allows to obtain data related to the work stage and file contents by displaying or print listing;
- completion of work session, giving notice for the execution stage end when a work period has been completed, showing the possibility to re-take it or close it finally;
- compress of files related to a work,which were made in more stations or files edited by the operator system, keeping the initial files, which the stations have carried out, until a new decision is made. Operators from each station can compress data of file which they carried out, as well. In such a case, block adjustment using independent models in a strip only can be started from each station, if it is required.

Using all facilities which a system can offer, all the data of a collected work are validated - from a photogrammetric stand point - carrying out point numbering checking in a strip, interior and relative orientation and successive model connections, and then they are recorded in proper files, thus being ready for aerial triangulation adjustment.

Computations are made in the system processor, using AERO 4 programme package - a conversational variant of the former AERO 3 version. These computations can automatically detect errors, which were not eliminated during data acquisition; some of these errors are automatically eliminated, the others are effectively eliminated by the photogrammetrist, which can instantly interfere in every computational stage, owing to the programme package facilities. After the gross errors and blunders have been eliminated, the adjustment is carried out, thus obtaining the final point coordinates inthe reference system and the necessary indicators, in order to estimate the acquired result precisions.

A unitary process is so accomplished, allowing the photogrammetrist to measure and detect gross errors and blunders, and to make computations.

At the same time, a close connection among the photogrammetric

plotting stages has been established, the aerial triangulation findings being directly used in the stereoplotting process for stereomodel relative and absolute orientations.
POLIFEM system use in aerial triangulation process decreases time necessary for aerial triangulation measurement and adjustment significantly; it, also, eliminates desadvantages mentioned from the very beginning, without resorting to expensive investments for photogrammetric equipment change.