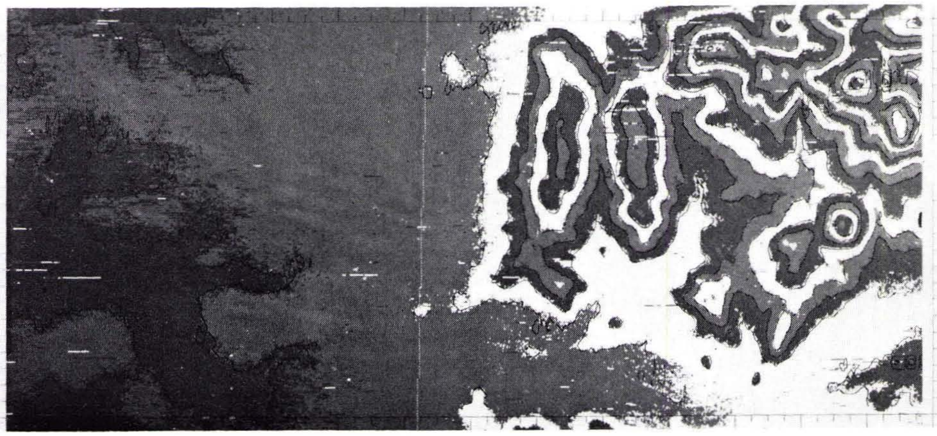

FRONTISPIECE. Computer produced contours superimposed on altitude chart output of the UNAMACE to show correlation.

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Automatic Contouring at the Army Map Service

Contouring digital data by computers is now practical.

(*Abstract on next page*)

INTRODUCTION

THE PRODUCTION OF topographic contours, in the compilation of maps, involves a great amount of time, labor, and expense. The present manual or non-automatic methods require an operator to view stereoscopic pairs of photographs and move a tracing table which draws the contours.

Recently, much research and interest has been oriented toward automating map compilation. There is a system, THE UNIVERSAL AUTOMATIC MAP COMPILATION EQUIPMENT,[1] known as the UNAMACE, which has shown results in this direction. The UNAMACE is a stereoscopic instrument which uses a pair of overlapping photographs to form a stereo model.

One output of the UNAMACE is a magnetic tape containing elevation data. The UNAMACE rapidly and accurately determines elevations by electronically locating and measuring corresponding images of the stereo model along profiles in the Y-direction. This elevation data can now be processed by a computer and converted into contour form. The resulting contour information is plotted or scribed by an XY-Plotter, thus automating the production of contours for map compilation.

Because it is expected at the Army Map Service that in the future extensive use will be made of automatic map compilation equipment, the authors have written a contour program which will provide another step toward the automation of map compilation.

PROGRAM ORGANIZATION

The contour program is written in MAP and Fortran IV programming languages under IBSYS Version 13, for the IBM 7094 computer. The program uses the overlay feature, and consists of four links which are organized in such a way that each link performs a particular function in the contouring process.

The purpose of Link 1 is to smooth the

[1] Bertram, S., "The Universal Automatic Map Compilation Equipment," PHOTOGRAMMETRIC ENGINEERING, Vol. 31, No. 2, March 1965.

elevation data from the UNAMACE magnetic tape output. The data from the UNAMACE contains accidental errors, which are called losses.

A Y-profile, in which a loss occurs, contains elevations which are very different from those in adjacent profiles. Losses are produced when the UNAMACE fails to track on the ground and rises above or falls below the surface. This is caused by factors such as poor photographic imagery, excessively rugged terrain, clouds, and bodies of water, and is corrected if the operator manually adjusts the tracking image to correspond to the terrain surface.

In order to detect more easily the loss errors, the Y-profile information is rearranged to form X-profiles. This is possible because elevation data is read at regularly-spaced intervals. Where losses are viewed along an X-profile, they appear as sharp spikes which extend only over short intervals. When Link 1 detects a spike of this nature, it replaces the value of the erratic elevation with the average of the elevations on either side of it.

The UNAMACE measures elevations in a profile sequence back and forth across a model. That is, it changes direction after measuring each succeeding profile, measuring one in the $+Y$-direction and the next in the $-Y$-direction, etc. As the UNAMACE correlates corresponding images from two diapositives and calculates the elevation of points, it is constantly moving the tables containing the diapositives. This mechanical movement will result in unavoidable systematic errors, a large portion of which may be removed through proper orientation and calibration.

In order to minimize the effect of this type of error, adjustments are made on the data after it has been changed to the X-profile form and the losses have been minimized. After considerable experimentation and plotting of profiles, it was decided that a second-order polynomial least-square adjustment over small overlapping sections of the X-profiles produced the best results.

Adjustments of an entire profile included too much data and required high-order polynomial curves to accurately follow the data. Profiles of rough terrain caused these polynomials to become quite erratic. By making adjustments over small intervals of the profile, a second-order polynomial curve satisfactorily follows the original data, yet smoothes out unwanted roughness. Even rugged terrain profiles, when taken over short intervals, do not cause the adjustment to be erratic. In order to maintain continuity between intervals it was discovered that the intervals had to be adjusted in over-lapping increments.

ABSTRACT: *Producing contours for map compilation formerly required many man-hours of tedious labor. Now, with the availability of automatic map compilation equipment, large-scale electronic computers, and XY-Plotters, automated contouring can be accomplished. Many tests with the UNAMACE magnetic tape output of elevation data have shown that satisfactory contours can be produced. Only slight touching-up is needed to give aesthetically adequate contours. With increased use and improvement in automatic map compilation equipment, automating the contouring process will relieve cartographers of many hours of manual labor and make more efficient use of their skills.*

The primary purpose of Link 2 is to determine the X and Y-values for points at which contours intersect the grid network formed by the smoothed X and Y-profiles (i.e., contour points). This is done by finding the grid square through which a contour passes and, using a linear interpolation, by determining the X and Y-value of the contour point.

As a secondary purpose of Link 2, an option exists to produce a more closely spaced grid network from the original grid. The grid spacing may be decreased to 1/2, 1/3, 1/4, or 1/5 the spacing of the original grid.

There are advantages to be gained by using this option. In very flat or very rough terrain, the more closely that contour points of one level are defined, the easier it is to connect up these points to form a proper contour. Instances occur, especially around drains, where the next consecutive contour point that has been defined is farther away than a point on another portion of the same contour. As a shorter distance is the basis of determining which will be the next contour point, gridding the profile data more finely produces more accurate and more continuous contours.

A definite disadvantage, which occurs when dividing up the original grid, is the ex-

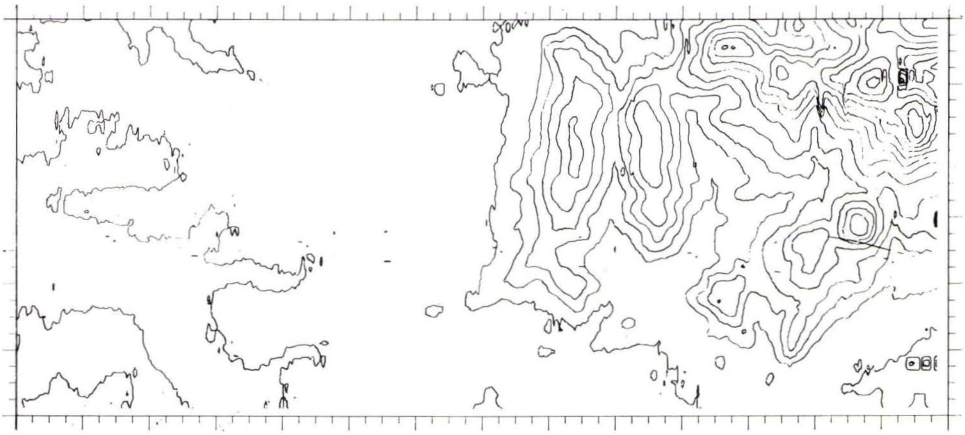

FIG. 1. Computer produced contours from UNAMACE digital data.

ponential increase in the number of points to be processed. This correspondingly increases the amount of computer time required to process a model. So, a median must be determined between the quality of the contours obtained and the cost in computer time required to obtain them.

Link 3 takes the contour points which are in profile form and converts them to points in contour form. That is, succeeding points will define a specific contour when entered into an automatic plotter program. Starting with the lowest contour elevation, all the points of a particular contour elevation are grouped together in an ordered sequence before proceeding to the next higher contour elevation.

Link 4, the last link, takes the points which are in a contour format and converts the X and Y-values of the points into instructions to move the pen of an XY-Plotter. This automatic-plotter routine programs the plotter to stop after it has finished plotting all the contours of a certain elevation. This allows for a change of pens so that contours of different levels may be color-coded. The plotting scale is variable, being limited only by the physical limits of the particular plotter that is used.

PROGRAM RESULTS

The contour program used in conjunction with an automatic map compilation instrument and *an XY*-Plotter, is able to supply contour information in a very short time as compared to manual methods. For example, a 3×7-inch model from the UNAMACE can be contoured and plotted in less than 25 minutes on the average. This time is variable depending on the grid spacing and the contour interval desired. With a grid spacing of 1/5 the original grid and a contour interval of 20 meters, the model in Figure 1 took 38 minutes to contour and plot. With the original grid spacing and a 20 meter contour interval the same model took 13 minutes to contour and plot.

Another output on the UNAMACE is an altitude chart (Figure 2). Obtaining contour information from an altitude chart may be time consuming, and the contour positions may be variable depending on the skill and experience of the cartographer who is tracing the contours. The contour program determines the contour position from the elevation data on the magnetic tape and therefore leaves no room for variability due to interpretation. (See the Frontispiece). The speed and consistency of the contour program gives it a decided advantage over manual methods of producing contours. Also, the contour program can give any contour interval and scale of output that is desired without recompiling the model on the UNAMACE, whereas the altitude chart output is limited in this respect. The user also has the ability to contour a particular portion of a model rather than contouring areas of no interest.

CONCLUSION

The magnetic tape output of elevation data from the UNAMACE can be used in the process of automating map compilation. A final map product cannot now be produced automatically from digital data without human assistance. However, it is believed that the manual labor and the amount of time now required for compilation will be minimized. Aestheti-

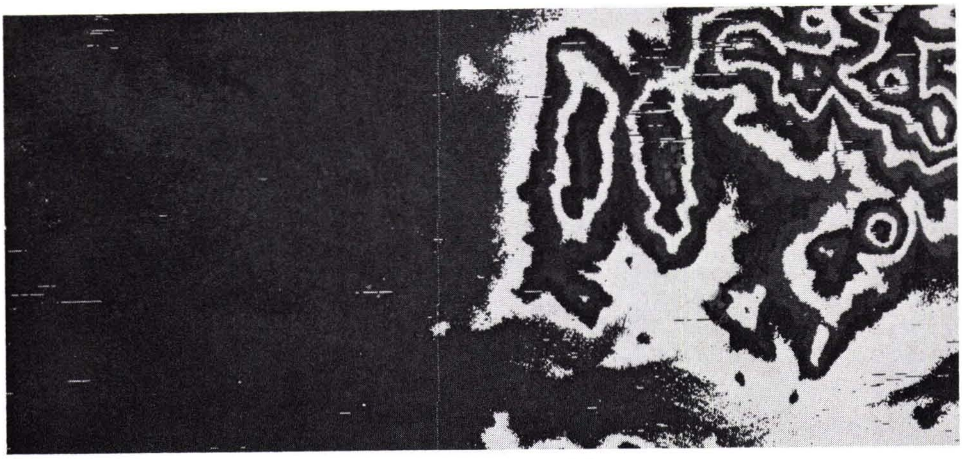

FIG. 2. Altitude chart output of the UNAMACE.

cally adequate contours, required by present mapping standards, should result when the contours that the computer can presently produce are touched-up by a skilled cartographer.

The contour program is by no means limited to the UNAMACE output. It can be readily adapted to other forms of input and output. As other automated systems are developed for acquisition of topographic information in numerical form, the authors believe a contour program in a form similar to the one they have written will be an invaluable tool in automating map compilation.

When computers with much larger memory capacities become available, it may be possible to write programs which will require even less human intervention in compiling maps. It is definitely believed that much further development is possible toward automating the mapmaking process.

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