ASTRA—A System for Automated Scale Transition

*F. W. Leberl** and *D. Olson*
MARKHURD Corporation, Minneapolis, MN 55426
W. Lichtner
Technical University, Darmstadt, Federal Republic of Germany

ABSTRACT: Existing 1:24,000 color separates are scanned automatically and raster-to-vector converted. The result is interactively edited using a technique called "escoding" (electronic sketch-controlled on display digitizing). This serves to create an intermediate set of topologically structured working files, e.g., for road network, vegetation, drainage, etc. This is then subjected to a series of automated generalization steps to include

- automated creation of high quality contour lines;
- automated building outline generalization;
- automated weeding of coalescing buildings;
- automated line smoothing;
- automated feature symbolization; and
- automated feature displacement.

The result of these processes is interactively checked, corrected, and prepared for output onto a precision plotting device.

INTRODUCTION

RAPID ACCEPTANCE of digital maps and computerized land information leads to a need to present the data at various scales. Therefore, a computer mapping system must have a component to take the contents of a digital data base and present it with varying symbolization and generalization.

A large body of literature exists on the subject of automated map generalization, addressing feature selection, line smoothing, shape simplification, symbol grouping, feature displacement, etc. Recent extensive bibliographies can be found in the doctoral theses of Menke (1983) and McMaster (1983). Work, however, has been confined mostly to academic cartographic environments; cartographic practice in industry and governmental mapping organizations has yet to enter this area of computer mapping.

Therefore, the commercial development reported on in this paper is unique; map data capture and generalization is performed employing a VAX computer, KartoScan raster scanner, and Intergraph raster refresh work stations. This automated generalization procedure is thus combined with a data capture system for Automated Scale TRAnsition—ASTRA. The following will describe the procedures using an example of a U.S. Geological Survey map at a scale of 1:24,000 and converting it first to a digital data base, then building from this a set of color separates for a map 1:50,000. The generation of the reduced display requires a minimum of manual intervention. Comparison with a manual process of scale transition reveals a currently achieved reduction of manual effort of 70 percent.

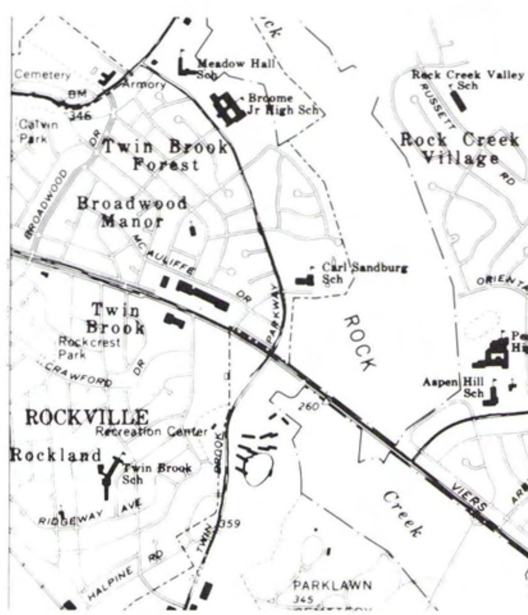

FIG. 1. Segment of an original color separate of a U.S. Geological Survey 1:24,000 scale map (Kensington and Rockville, Maryland) (reduced to 1:32,000 scale).

*Presently with VEXCEL Corporation, Boulder, CO 80301.

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 52, No. 2, February 1986, pp. 251–258.

0099-1112/86/5202-251$02.25/0

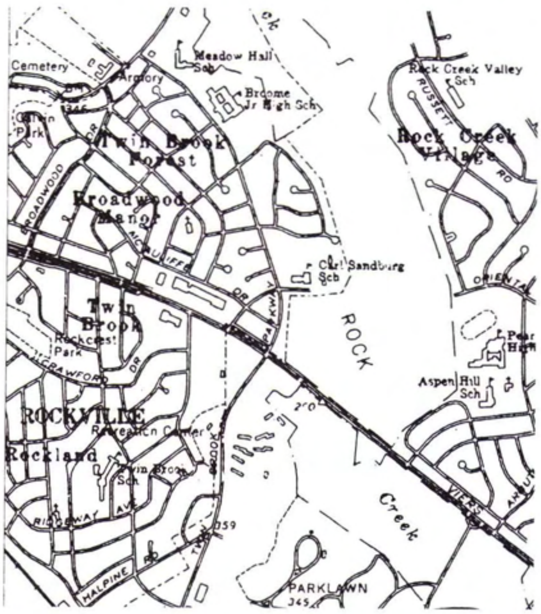

FIG. 2. Raw vectorized data of map segments from Figure 1 (reduced to 1:32,000 scale).

DATA CAPTURE

Figure 1 is the black composite plate as an example of one of several original color separates for a 1:24,000 scale map showing an area used for tests by the U.S. Geological Survey. Converting these data to a digital format can be done with any one of several techniques. An efficient approach is by raster scanning and subsequent raster-to-vector conversion. This works well with uniform data such as those from the contour, drainage, and vegetation separates.

Figure 2 presents raw "vectorized" examples of each of the originals of Figure 1, as they have gone through the automated digitizing process. The KartoScan cartographic scanner is used in a process as described earlier (Leberl and Olson, 1982). No manual editing has been applied to the data of Figure 2. It is evident that the black composite plate needs considerable correction after data conversion; the other data are geometrically and esthetically acceptable but require topological corrections; one may have to remove redundant nodes, bridge gaps, and clean noise.

In the current ASTRA system we employ several techniques to correct the raw vectorized data. One of particular interest and efficency is the so-called "Electronic Sketch Controlled On Display" digitizing—"escoding." For this purpose the vectorized data are loaded into the work station and an interactive process is initialized to

- produce centerlines based on contours of linear features,

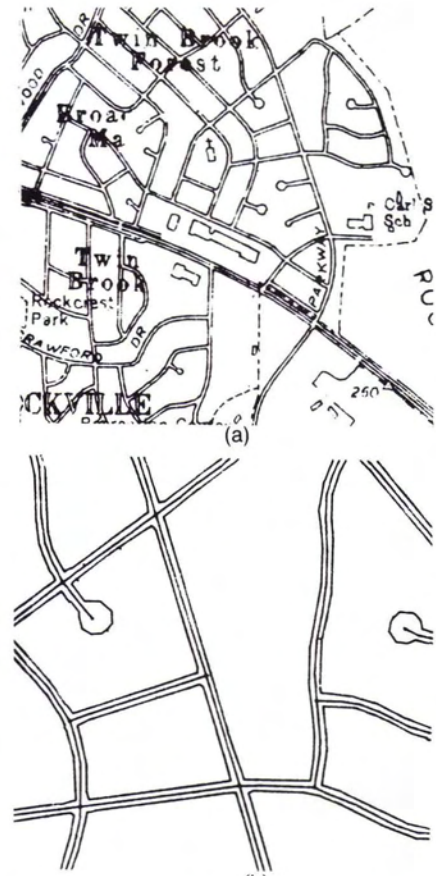

FIG. 3. Escoding—electronic sketch controlled on display digitizing. (a) Electronic sketch. (b) Enlarged sketch and digitized lines.

- generate rectangular houses, and
- exchange irregular symbol shapes by predefined symbols.

An example of this process of "escoding" is shown in Figure 3. The procedure is interactive and under operator control; this is advantageous because it provides quality control, acceptance, and on-line resolution of ambiguities. The degree of automation of "escoding" is progressing as new algorithms are implemented.

Escoding is meaningful in the event where the data are highly symbolized. Figure 4 is one example of a symbolized feature on the original map, in the vectorized data file, and as it is ultimately "escoded" and ready for storage in a data base.

We currently only produce geometric centerline information with a manually added label. The exact shape of the features from which the information is derived is lost. Therefore, it is not possible to reconstruct the original map unambiguously. Figure 5 is an example where two features produce similar

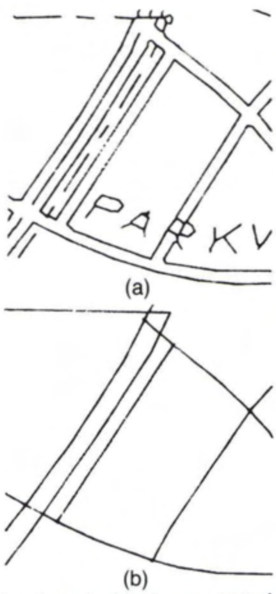

FIG. 4. Example of symbolized, raw vectorized feature and escoded data. (a) Raw vectorization. (b) Escoded.

digital information although their analog sources are different.

Polygon data undergo an additional logical check to verify their topological validity. Figure 6 is an example where the raw vector data shows gaps; polygons are not necessarily closed. Polygon processing software will flag such problems and allow an operator to correct the error and verify the topological correctness of the digital data.

FORMATTING FOR PERMANENT DIGITAL STORAGE

The internal working data structures need to be converted to a format as specified by a user of the data. This may be vastly variable. In the United States very common systems are those of the U.S. Geological Survey (DEM and DLG) or of the Defense Mapping Agency (DTED and DFAD). Such permanent storage formats are trivial to generate, with the exception of topographic relief. This is usually in the form of a digital terrain model so that a raster of height values must be created.

To obtain a high quality terrain height raster requires sophisticated interpolation and quality control routines to be available. We have repeatedly described various systems; the one available in ASTRA has been discussed by Leberl and Olson (1982).

LINE SMOOTHING

A large variety of algorithms exists to smooth linear features for generalization. The requirement to produce a graphical result differs from that of creating a compact digital record of a line. "Smoothing" therefore can have two meanings: reduce the number of points to describe a line, or create a smooth graphical line presentation. The latter does not necessarily imply a reduction in the number of points used for line representation.

Simple algorithms just check a sequence of three points and the distance of the center point from the line connecting points 1 and 3. This must be applied repeatedly and leads to poor results. A popular algorithm is by Douglas and Peucker (1973), employing a so-called "corridor." One begins with starting and end points to form a straight line. One then searches for the first point along the input line to be farther away from the straight line than a minimum, ϵ. If such a point is found, it is made a new starting point. Other points are dropped. This algorithm also leaves an unnecessary high number of points.

A new technique has been described by Dettori and Falcidieno (1982). It is also based on a critical value, ϵ, but the searches are more elaborate than in the method of Douglas and Peucker (1973). We have employed the algorithm of Dettori and Falcidieno (1982). Figure 7 is an example obtained with this technique, applied to a drainage line of the test data set.

CONTOUR LINES

Using the digital terrain model, it is straightforward to generate a contour line plot at an arbitrary interval. We employ program TASH as part of ASTRA. TASH has been developed and described by

(a) (b) (c) (d)

FIG. 5. Two different original features produce similar digital data. (a) Raw feature 1. (b) Digitized feature 1. (c) Raw feature 2. (d) Digitized feature 2.

FIG. 6. Raw vector data and topologically verified version with test on validity. (a) Raw vectorized data. (b) Symbolized and check-plotted; polygon is filled to verify topological correctness of closed polygon.

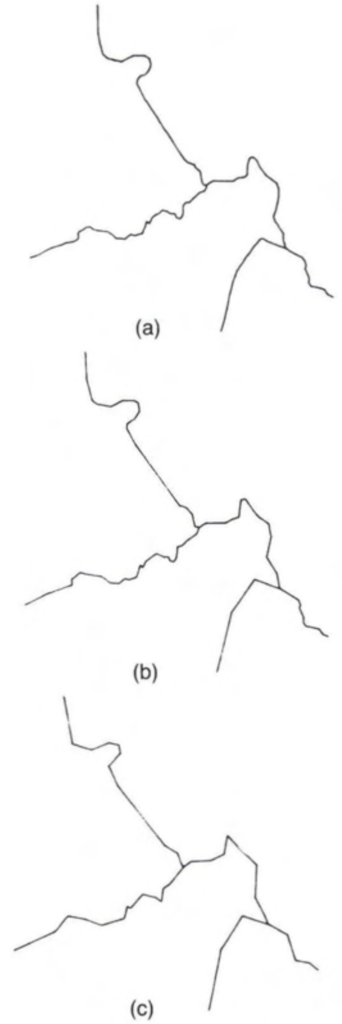

FIG. 7. Example of input line and point weeding for line smoothing; note how characteristic points remain unsmoothed. (a) Unsmoothed. (b) Smoothed.

Kruse (1979) and others. Figure 8 is a result for the test area.

GENERALIZATION OF THE OUTLINES OF BUILDINGS

Figure 9 displays several buildings both in the input and output format. The generalization is a simplification of the outline based on longitudinal dimensions. In principle, features smaller than a certain limit are suppressed. In the current case, elements are neglected if smaller than 0.2 mm at the 1:50,000 output scale of the map.

The algorithm has been proposed by Lichtner (1979) and is part of a batch generalization process of ASTRA.

COALESCING OF FEATURES

House symbols that are close to one another can be weeded or combined in a reduced scale. Figure 10 is an example. The method used is based on a chosen critical distance of 0.3 mm. Coalescing of features is a program that works in conjunction with feature simplification.

SYMBOLIZATION

Of course, the centerlines and point symbols in a data base must be symbolized for display. This is mainly determined by a user. A symbol library must be employed to properly translate internal feature codes into the display. Figure 11 is one example that takes road centerlines and house symbol positions

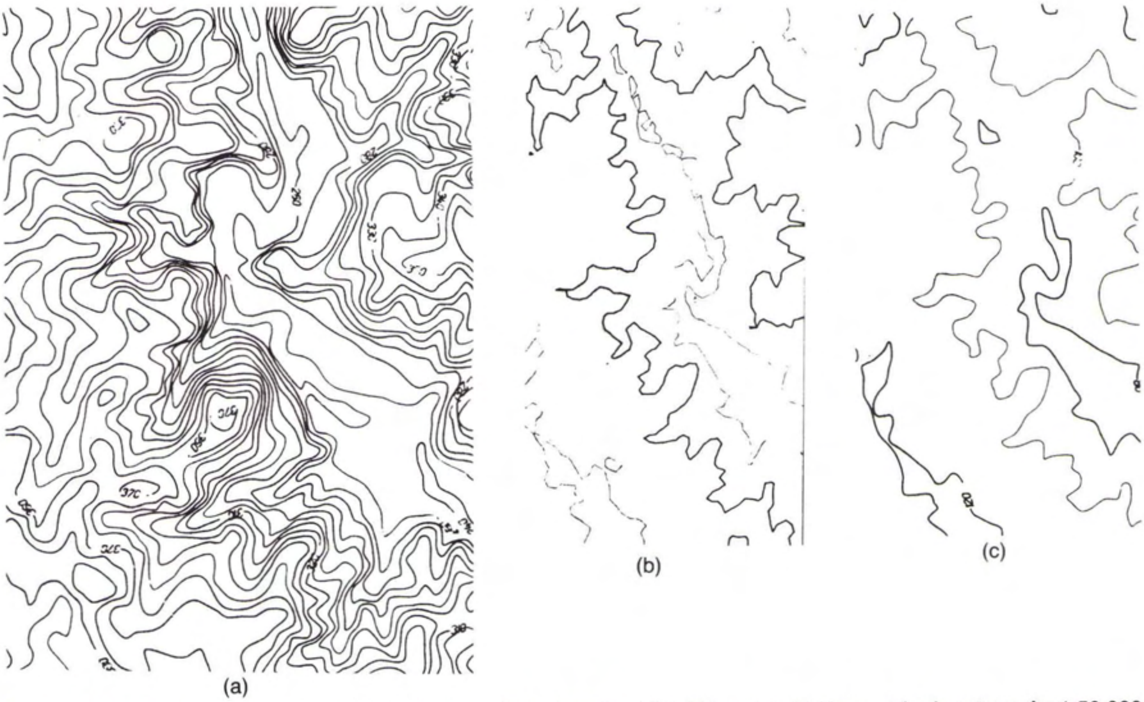

FIG. 8. Input and output contour lines. (a) 1:24,000 scale (reduced to 1:32,000 scale). (b) Unsmoothed contours for 1:50,000 scale (reduced to 1:66,667 scale). (c) Smoothed contours for 1:50,000 scale (reduced to 1:66,667 scale).

FIG. 9. Building outline simplification. (a) Raw 1:24,000-scale data (reduced to 1:32,000). (b) Generalized building outlines.

as well as orientations to create a symbolized display.

FEATURE DISPLACEMENT

Scale transition presents a requirement of changing not only the number but also the position of features. Figure 12b is an example of cluttered and overlapping features as they result from symbolization. It is common cartographic practice to displace features with respect to one another to resolve the clutter and to achieve improved readability.

ASTRA contains an algorithm first proposed by Lichtner (1976) to shift features according to a user selected priority. The application of this technique leads to the result in Figure 12c.

OVERALL GENERALIZATION RESULT

The combination of various generalization steps leads to final output color separates as shown in Figures 13a and 13b. These are produced in an automated manner on a precision plotter using scribing, a photo head, a laser plotter, or an electron beam recorder. The example in Figures 13a and 13b was obtained from a Kongsberg precision plotter using a scribe tool.

The manual effort in the machine generalization within ASTRA must be compared with a manual cartographic effort. The graphical result from a traditional scribing technique is shown in Figures 13c and 13d. The amount of manual work is three times greater. Automated techniques require, therefore, a fraction of the effort done in traditional methods.

CONCLUSION

We have presented a procedure for automated

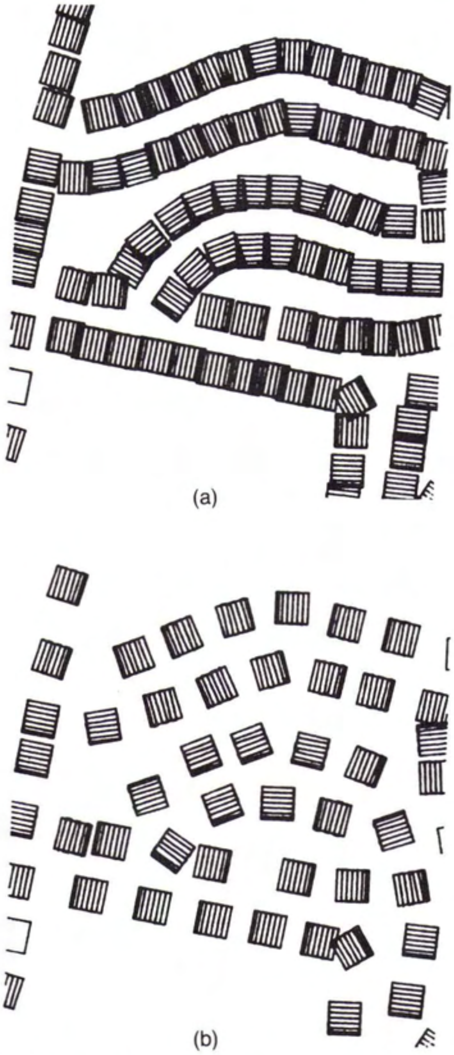

FIG. 10. Coalescing house symbols. (a) Raw 1:24,000-scale data. (b) 1:50,000-scale conversion.

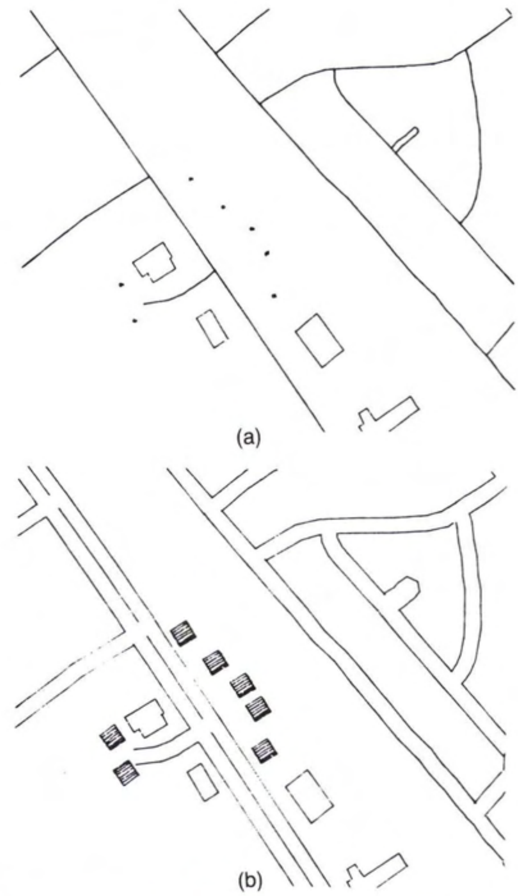

FIG. 11. Symbolized roads and houses. (a) Check plot of data base. (b) Symbolized content of data base.

scale transition of topographic maps, denoted "ASTRA"; it has been illustrated step by step using the example of a transition from 1:24,000 to 1:50,000.

The overall process is fairly elaborate because it requires the generation of a digital map data base. The overall effort to go by means of a digital technique is high. However, once the data exist, it is rather efficient to produce an output at a different scale. Disregarding the effort made to create the digital base, we currently achieve about a three to one improvement in speed and throughput with automated generalization over manual methods. This same ratio may not apply to costs because one has to use specific computer equipment.

The main advantages of the digital generalization are well-known: i.e.,

- objective results,
- independence from skilled cartographers, and
- speed.

Disadvantages are the comparatively poor cartographic esthetics that are usually obtained in a computer. The above mentioned speed advantage may not also convert to a cost advantage.

ASTRA is an operational capability that can be applied in a variety of circumstances. Data capture, of course, is very widely applicable in all conversion tasks; generalization is required when a legible, esthetic, and meaningful display of digital data must be produced.

ACKNOWLEDGMENTS

Many programs had to be written for ASTRA to create it from standard KartoScan and Intergraph systems. Programming efforts were mainly done by Randall Knippel, Richard Buenger, and Kent Holland from MARKHURD, and by Ingo Kruse and Her-

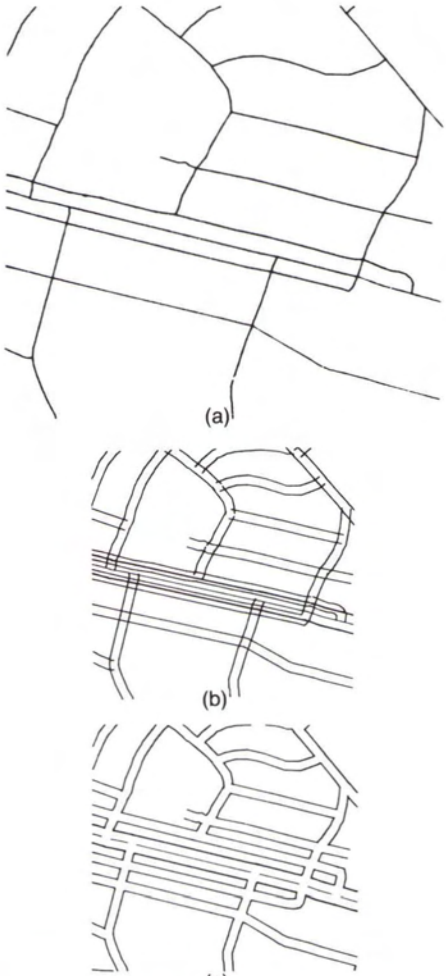

FIG. 12. Area with overlapping features before and after displacement. (a) Raw digital 1:24,000-scale data. (b) Symbolized raw digital 1:50,000-scale data. (c) Cleaned 1:50,000-scale digital data after displacement.

wart Seifert from the University of Hannover. We appreciate their dedication.

REFERENCES

Dettori, G., and B. Falcidieno, 1982. An Algorithm for Selecting Main Points on a Line. *Computers and Geosciences*, Vol. 8, No. 1, pp. 3–10.

Douglas D., and T. Peucker, 1973. Algorithm for the Reduction of the Number of Points Required to Represent a Digitized Line or its Caricature. *Can. Cartog.*, Vol. 10, No. 2, pp. 112–122.

Kruse, I., 1979. TASH – Ein System zur EDV-unterstuetzten Herstellung topographischer Grundkarten. *NaKaVerm* I/79, IFAG Frankfurt am Main.

Leberl, F., and D. Olson, 1982. Raster Scanning for Operational Digitizing of Graphical Data. *Photogrammetric Engineering and Remote Sensing*. Vol. 48, No. 4, pp. 615–627.

Lichtner, W., 1976. *Ein Ansatz zur Durchfuehrung der Verdraengung bei der EDV-unterstuetzten Generalisierung in topographischen Karten*. Wissenschaftliche Arbeiten der Fachrichtung Vermessungswesen der Univ. Hannover, No. 66.

———, 1979. Computer-Assisted Processes of Cartographic Generalization in Topographic Maps. *Geo-Processing*, Vol. 1., p. 183.

McMaster, R., 1983. *A Quantitative Analysis of Mathematical Measures in Linear Simplification*. Ph.D. Thesis, Dept. of Geography-Meteorology, Univ. Kansas.

Menke, K., 1983. *Zur rechnergestuetzten Generalisierung des Verkehrswege- und Gewaessernetzes, insbesondere für den Masstab 1:25,000*. Wissenschaftliche Arbeiten der Fachrichtung Vermessungswesen der Universitaet Hannover, No. 119, FRG.

(Received 22 September 1984; accepted 9 August 1985)

FIGURE 13 ON FOLLOWING PAGE

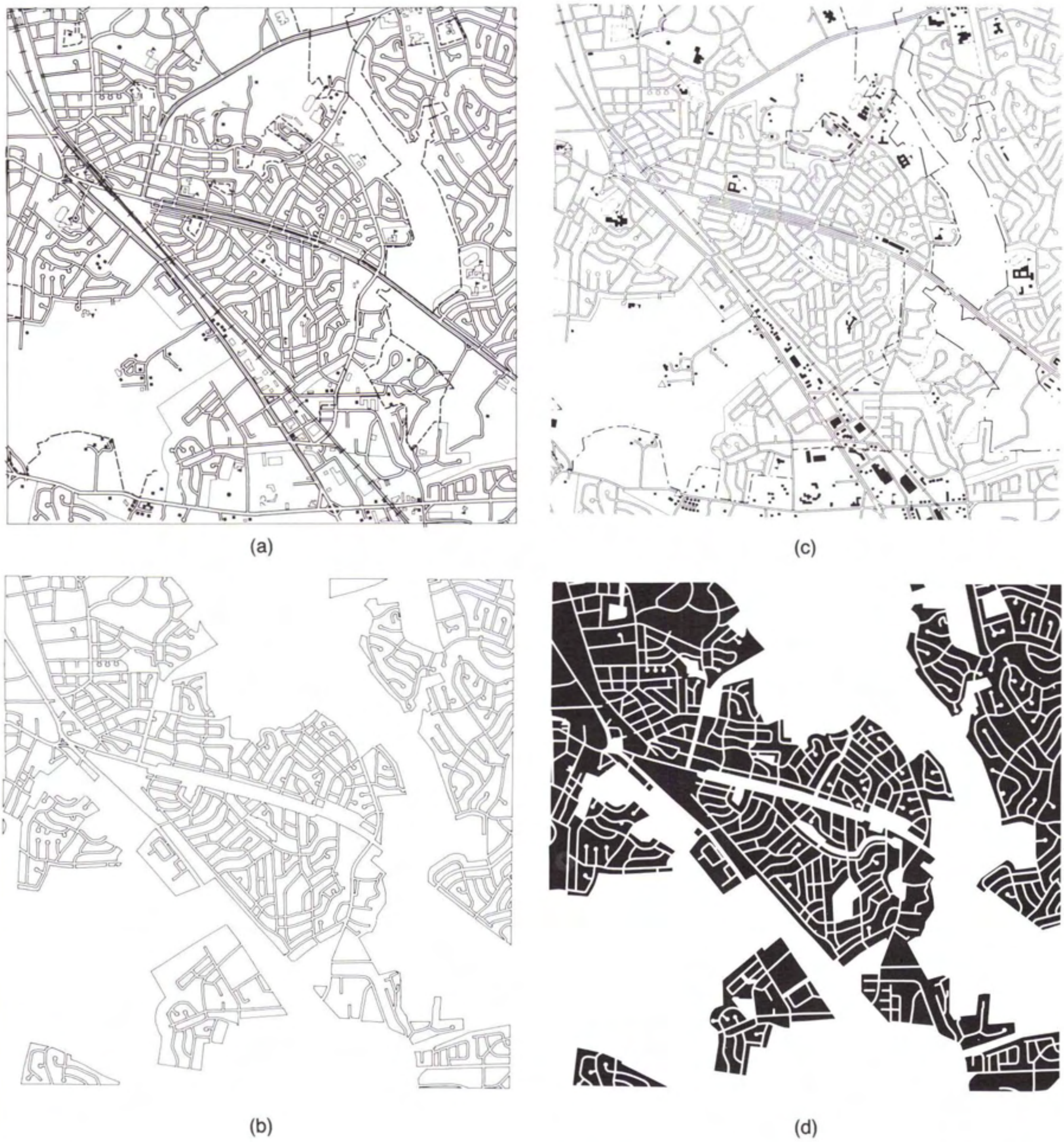

FIG. 13. Final output color separates, obtained from digital 1:24,000-scale data in (a) and (b), and obtained manually in (c) and (d). Note that machine scribed areas are not filled automatically; filling is achieved by manual stripping. Areas could be automatically filled if a raster plotter were used. (a) Black composite from digital 1:24,000-scale data (reduced to 1:32,000 scale). (b) House omission plate from digital 1:24,000-scale data (reduced to 1:32,000 scale). (c) Black composite obtained manually from 1:24,000-scale reductions (reduced to 1:32,000 scale). (d) House omission plate obtained manually from 1:24,000-scale reductions. (reduced to 1:32,000 scale).