INTERSECTING LAYERS OF INFORMATION - A COMPUTERIZED SOLUTION

Y. Doytsher & B. Shmutter

Technion, I.T.T., Haifa, Israel

ABSTRACT

The geographical data base as a replacement of the line map is steadily gaining ground among the map makers and map users. With all the possibilities it renders with regard to data processing, one has to admit that at least in one respect, in displaying information, the data base poses problems, particularly when the display is not merely an act of copying its content. Such problems usually relate to overlaying information, classification of data and plotting the results each class separately on an individual sheet. Separating the information is essential for reproduction purposes.

The paper discusses various aspects of the problems related to overlaying information, problems such as intersecting polygons, identifying polygons encompassed by other polygons, defining closed figures constituting segments of polygons and segments of the frame of the map and so on.

The data processing is carried out without resorting to manual intervention and without being assisted by special purpose equipment.

INTRODUCTION

Sets of polygons each being characterized by a specific quality and defined over a certain area, represented by maps, a DTM or photogrammetric models, are regarded as constituting a layer of information. The sum of the areas of the polygons distinguished by the qualities specifying the information is usually a part of the entire area being analyzed. The remaining areas are regarded as forming complementary polygons, referred to in the following as "zero polygons". Generally, more than one layer of information may be defined over a given area, in such an event the zero polygons are composed of areas deficient in all the qualities being considered.

The term polygon usually implies a closed figure whose whole area is associated with its perimeter. In the present case that term is being used in a more general sense, it is applied also to figures with voids, meaning that an area related to a polygon is not necessarily equal to the area circumscribed by the outer perimeter, and that the figure itself may be bounded by more than one perimeter, by the outer perimeter and eventually by a number of inner perimeters encompassing the voids. An example of such a polygon would be the abovementioned zero polygon.

A perimeter of a polygon is constituted of strings of points each point being determined by coordinates. Such a string is characterized by the fact that the areas on either side of it carry different qualities, from which follows that in addition to the coordinates, the strings of points are defined also by attributes describing the properties of the terrain or the terrain cover being the subject of the inquiry.

Although the entire area under consideration may be represented by several map sheets or models, it is referred to in the following as the map. Accordingly, the perimeter of the area is referred to as the frame of the map.

Having established layers of information a variety of cartographic and statistical problems concerning the map can now be solved. Since all the components of the information layers are described numerically, in terms of coordinates, solutions of a pure computational nature, executable on commonly available and general purpose equipment, such as a computer and a plotter, can be devised, without resorting to specialized and expensive systems. Such an approach excels in an additional respect - it is fully computerized and does not necessitate manual intervention during the processing.

ESTABLISHING LAYERS OF INFORMATION

Subdividing the map into polygons can be carried out in two ways:

a - Computing coordinates of points composing the perimeters of the polygons from topographic data (DTM). Typical problems of such a case would be forming a slope map, - delineating dead ground with respect to given observation points, preparing layered maps etc.

b - Digitizing coordinates of points along boundary lines of polygons traced on existing maps. Problems exemplifying that situation would be the classification of areas according to the land use.

Forming a topographic layer of information is suitably demonstrated by the operations required to produce a slope map. The problem here is to delineate areas within which the maximal slope of the terrain does not exceed given values. At the first stage terrain slopes are computed at discrete points, thereafter points marked by predefined slope values are concatenated to form strings. A string so obtained may close on itself, in which case it forms a polygon, or remain unclosed, thus starting and terminating at the frame of the map. Regarding the closed figures it is required to identify whether such a figure contains another figure, or is contained in a figure, or may be both events take place. Regarding the open strings, these are linked together with segments of the frame to form closed polygons.

Upon completion of the above operations the whole map becomes subdivided into polygons thus furnishing the required information layer.

Each of the polygons being identified separately, a question may arise as to the correctness of the subdivision of the map. That can be verified by imposing two conditions on the process; no string of points should remain open, the sum of the areas of all the polygons computed from the coordinates of the perimeters including the zero-polygons should equal the area bounded by the frame of the map.

The second possibility to define layers of information is based on using an existing map digitizing perimeters of polygons traced on the map. There too, various operations have to be performed to finally produce the information layer.

First of all, the digitized data are transformed to the state coordinate system, the transformation allowing for deformations of the material on which the map is drawn.

Many of the polygons are figures of irregular shapes the perimeters of which are not composed of segments of straight lines connecting distinctly defined vertices. Besides, to facilitate the digitizing process, each polygon is being digitized separately. As a result, adjoining polygons may overlap slightly, or narrow gaps may appear between them. In both cases it becomes necessary to eliminate these deviations and to merge strings of points in order to uniquely determine common segments of perimeters describing bordering polygons. A polygon should be determined as a closed figure, implying that the starting and terminating points of its perimeter coincide. Because of the peculiar shapes of the lines forming the perimeters that requirement is not necessarily met during the digitizing procedure, hence it has to be fulfilled at the stage of processing the data. Another requirement is laid down on the open lines which are digitized. These should terminate at the frame of the map in order to enable forming polygons, the perimeters of which include segments of the frame.

Other operations related to establishing an information layer have been considered above and need not be repeated here.

INTERSECTING INFORMATION LAYERS

In order to elucidate the intersection problem the following example may be considered. Suppose that two information layers have been identified in a given area;
I - a slope map consisting of three classes of slopes,
II - a layer composed of four types of vegetation.
A question may arise how types of vegetation are distributed with respect to areas characterized by slopes.
To answer such questions, the information layers have to be intersected, or, as it is frequently said, overlayed. The intersection as such can be defined as a procedure which determines areas shared by polygons of the layer I carrying the specific quality "A", and polygons of the layer II distinguished by the quality "B". Essentials of the algorithm underlying the intersection procedure are given in (1).

Referring to the example above, the intersection of the two layers may provide 12 types of areas, each being marked by a different combination of vegetation and slope, these 12 types being obtained by overlaying each class of polygons of the layer I on every one of the classes of polygons of the layer II.

Since only two classes of polygons always participate in the intersection procedure, there is no necessity to provide all possible combinations in all cases. The procedure can also be applied selectively to define areas distinguished by a combination of two qualities, "A" of layer one and "B" of layer two. The result of that intersection, forming a new class of polygons, can now be overlayed on a class of polygons with the quality "C" of a third layer of information (if such a layer exists), thus providing areas characterized by the three qualities "A", "B" and "C", and so on.

Carrying out all required intersections with respect to all information layers subdivides the map into n definite classes of polygons, each being marked by a different combination of qualities, including the zero-polygons, those which are defficient in all qualities being considered. At all stages, the processing maintains the fulfillment of the condition that the sum of all areas of all polygons should equal the area delimited by the frame of the map.

It is worth noting that the results of the processing are always expressed in terms of coordinates, a fact of great importance for various applications.

DISPLAY OF DATA

There are two ways to display the results of the processing:

a - Plotting all the information on one single drawing
b - Producing a "colour separation".

The first case offers no difficulties, discriminating between the various types of polygons on the drawing is effected simply by different hatchings of their areas.

The second case is more complicated, the areas of the polygons have to be "painted", and each class of polygons has to be displayed on a separate sheet.

Separating classes of polygons is a straightforward procedure, because of the digital description of their perimeters. However, the "painting" of the areas is more complex, since in the present case it is designed to be performed by a plotter.

Figure 1 illustrates the various aspects of the "colour separation".

Diagram a on figure 1 represents schematically a subdivision of a map into three classes of polygons A,B,C.

The colour separation is shown on three individual sheets represented by the diagrams c,d, and e, diagram c corresponding to class A, d to B and diagram e to class C.

Diagram f depicts the three classes "printed" in three colours over the existing map.

Covering the area of a polygon with colour by means of a plotter is accomplished by a very dense hatching of the area, dense to such a degree that the lines become tangent. (That was not shown on the above diagrams for graphical reasons).

To cover the area in an effective way the hatching is made of wide lines which entails using a pen of a considerable diameter. In order to cover the area properly the lines

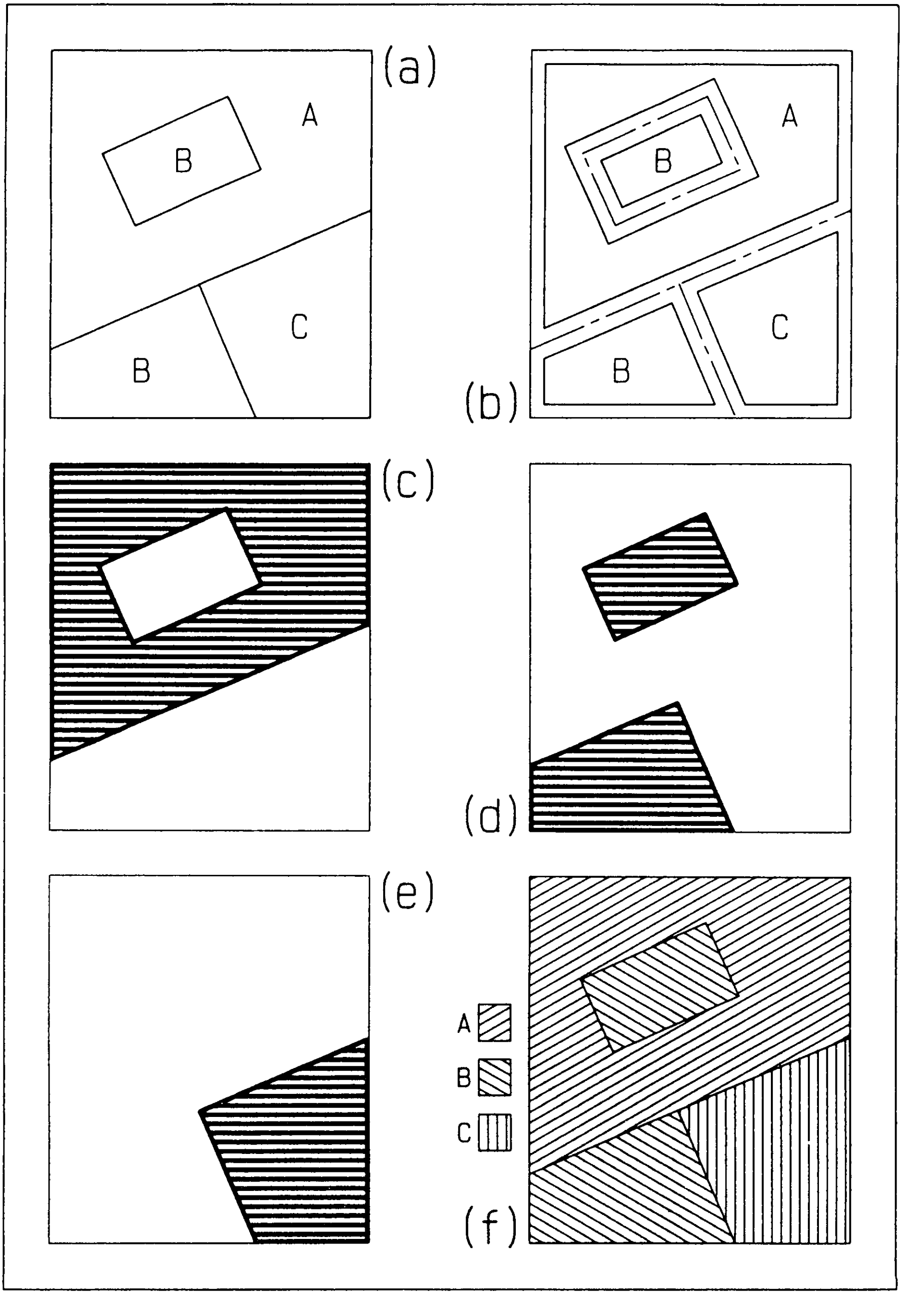

Figure 1: Display of Data

drawn within it should start and terminate at the boundary lines of that area. It is the feature of the plotter, that when a line is drawn its extremeties coincide with the positions occupied by the center of the pen. Therefore, if a wide pen is used, its center will arrive at a predefined point, but because of the width, the line actually plotted will extend beyond that point. Hence, if the area as such is being hatched its boundaries are becoming blurred. To avoid that effect and to maintain distinct boundary lines, the areas of the polygons are contracted slightly by displacing the boundary lines parallel to themselves at an amount equal the radius of the pen. The result of that operation is demonstrated by diagram b on figure 1, where the original boundaries are plotted as thin broken lines and the shifted boundaries as heavier lines.

EXAMPLES

Figure 2 illustrates an intersection of layers of topographic information.

Figure 2a shows a segment of a topographic map of the area (contours and hydrography generated from the DTM).

Figure 2b represents a map of dead ground derived from the DTM with respect to two observation points (marked on the map). That is already a superposition of two maps, each one being related to one observation point.

A slope map produced from the DTM data is depicted in figure 2c. Three classes of areas have been defined, areas with slopes not exceeding 10%, areas within which the maximal slopes vary between 10% and 30% and areas where the slopes exceed 30%. The areas are represented by different hatchings, areas more densely hatched corresponding to steeper slopes.

The intersection of the slope map with the map of dead ground is presented on figure 2d. As a result of the intersection the polygons of the dead ground have been subdivided into three classes in accordance with the distribution of the slopes. For example, the sparsely hatched polygons represent dead ground where the maximal slope is less than 10%.

It is worth noting that figure 2d is a result of combining three layers of information, each polygon of that figure carries three qualities: Its area cannot be observed from two given points and the slopes related to it are within a predetermined range.

Figure 3 depicts a case of intersecting information layers derived from an existing map. The area of the map segment

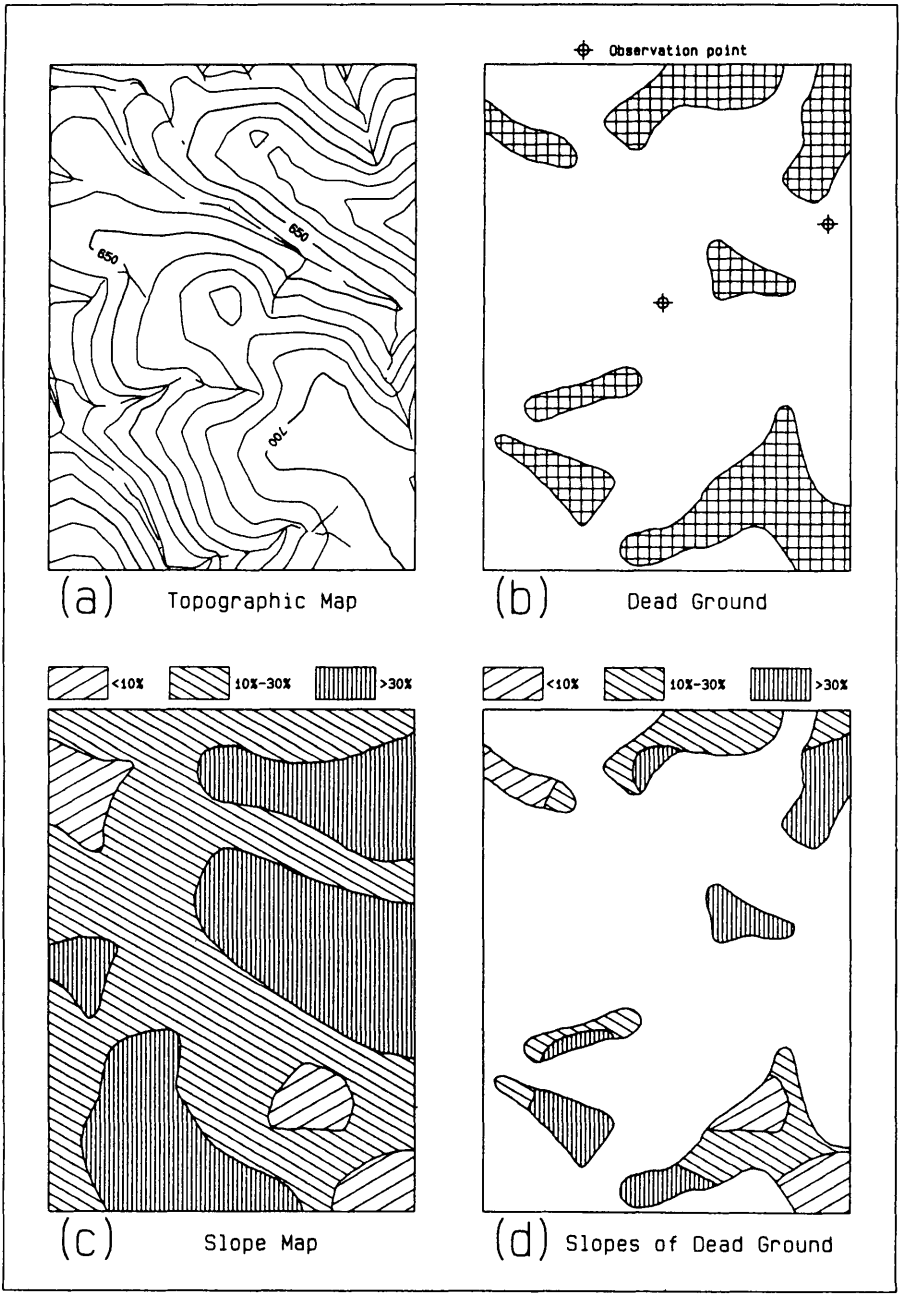

Figure 2: Topographic Information

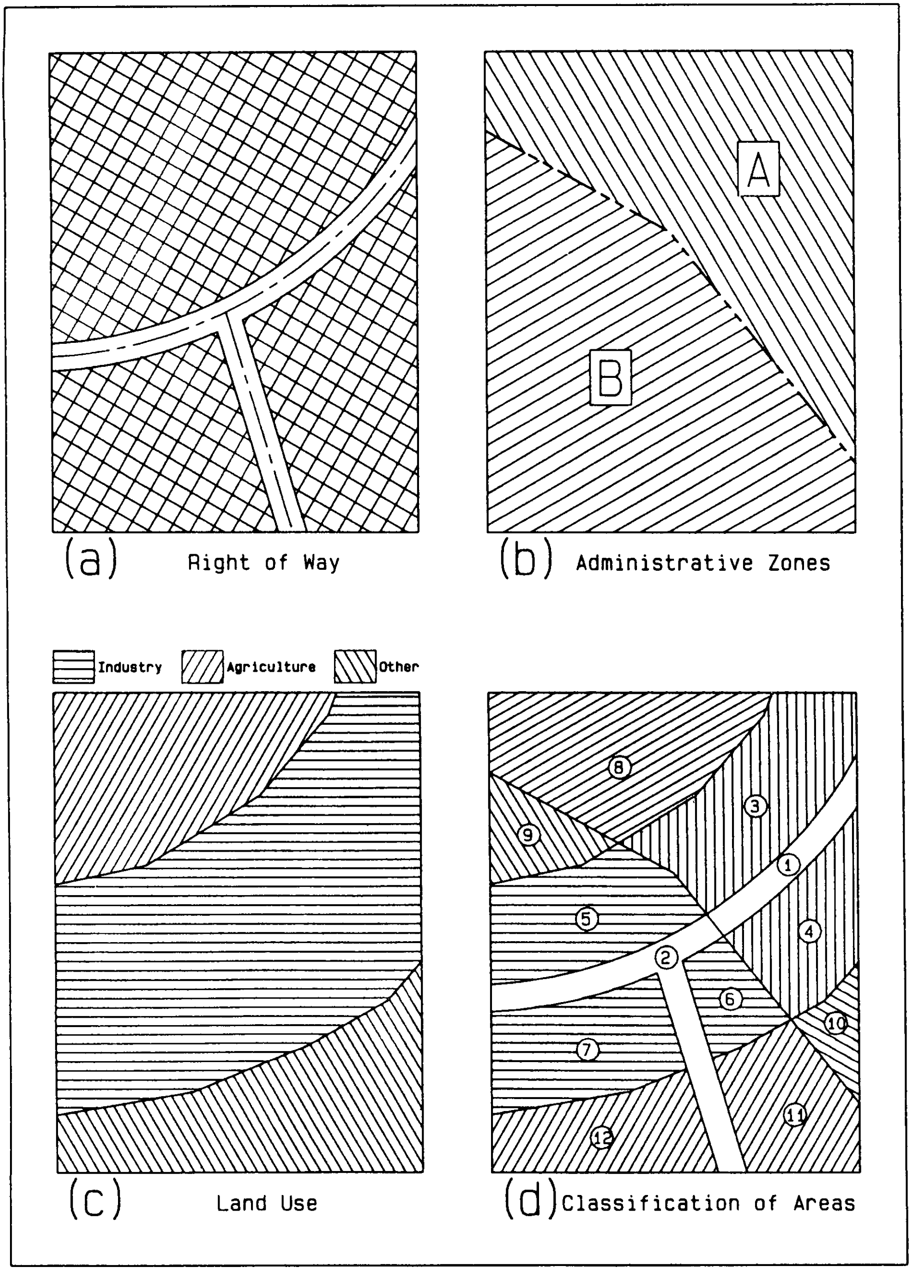

Figure 3: Land Use

is subdivided into classes of land use: Agriculture, industry and other, as shown on diagram c and strips defining the right of way as depicted on diagram a. The administrative subdivision of the area is presented on diagram b. The overlaying of the land use information on the administrative zones is represented by diagram d. Twelve polygons have resulted from the overlaying operations, five in zone "A" and seven in "B". Statistical data about those polygons are given in the table below.

Land-Use	Administrative Zones				Total	
	A		B			
Right of Way	1 26.940		1 59.357			
	26.940	7.2%	59.357	12.8%	86.297	10.3%
Industry	3 123.476 4 68.059		5 91.364 6 33.596 7 89.141			
	191.535	51.1%	214.101	46.0%	405.636	48.3%
Agriculture	8 135.249		9 38.201			
	135.249	36.1%	38.201	8.2%	173.450	20.6%
Other	10 21.276		11 75.481 12 77.860			
	21.276	5.6%	153.341	33.0%	174.617	20.8%
Total	375.000	100.0%	465.000	100.0%	840.000	100.0%

Table Nr. 1: Classification of Data

Both columns labeled A and B present the areas of the polygons yielded by the intersection, in absolute and relative numbers (percentage).

SUMMARY

Intersecting layers of information, sorting, separating and displaying the results are useful in many respects. In the paper a possibility is presented for using an ordinary plotter suited to smaller mapping organizations in this field. The solutions for the problems discussed in the paper are of a pure computational nature, no intermediate display of data and no interactive work stations are being required, thus eliminating any need for human intervention during the processing and devising thereby a fully automated procedure.

REFERENCES

1. Shmutter, B. & Doytsher, Y.(1986)-Computerized Solution for Land Subdivision.To be published in the June issue, 1986 of the Canadian Surveyor.