Commentary

On Distinctions among Cartography, Remote Sensing, and Geographic Information Systems

Peter F. Fisher and *Richard E. Lindenberg*
Department of Geography, Kent State University, Kent, Ohio 44242-0001

ABSTRACT: The growth of automation in cartography and the development of the fields of remote sensing and geographic information systems (GIS) have led to a situation where the subject matter of each is poorly defined with respect to the others. From a review of the literature, a number of models of interaction are identified among these fields, and the alternatives are explored. In the favored model, the three fields each have a unique domain, as well as two-way and three-way interactions.

INTRODUCTION

CARTOGRAPHY, remote sensing, and geographic information systems (GIS), together with geodesy, photogrammetry, and surveying are among the mapping sciences. From a review of current definitions of the first three fields, it can be demonstrated that there is considerable overlap in their extent. Depending on the definition selected, either cartography or GIS can be interpreted as totally subsuming the activities that might be claimed by the other fields. It seems unacceptable to have a number of clearly related fields for which the boundaries are poorly defined and the interrelationships are unclear. A number of papers have attempted to clarify the boundary between remote sensing and cartography (Henderson, 1978; Dahlberg and Jensen, 1986), and Cowen (1987a, 1987b, 1988) has variously addressed the distinctions among GIS, computer mapping, and database systems. No one, however, seems to have attempted to define the three-way interaction of GIS, cartography, and remote sensing.

This paper reviews the definitions of cartography, remote sennsing, and geographic information systems, and based on these, a number of models are presented to show different interpretations of how the three interact. The arguments presented here are a refinement on those given by Lindenberg and Fisher (1988).

DEFINITIONS

CARTOGRAPHY

The fifth edition of *Elements of Cartography* starts "an appropriate question at the beginning of this book is: What is cartography?" (Robinson *et al.*, 1985, p. 1). Not many pages are turned before an answered is supplied:

> *Definition 1*
> This graphic representation of spatial relationships and spatial forms is what we call a map, and, very simply, cartography is the making and study of maps in all their aspects. ... . This includes teaching the skills of map use; studying the history of cartography; maintaining map collections with the associated cataloging and bibliographic activities; and the collection, collation and manipulation of data and the design and preparation of maps, charts, plans and atlases (Robinson *et al.*, 198, pp. 1–3).

The authors later go on to delineate "conceptions of cartography" which are areas of emphasis within cartography (pp. 11–17). Important for this discussion, the scope of cartography is identified as having four categories:

> *Definition 2*
> - Collecting and selecting the data for mapping;
> - Manipulating and generalizing the data, designing and constructing the map;
> - Reading and viewing the map; and
> - Responding to or interpreting the data (p. 17).

These tasks of the cartographer have recently been reiterated by Carter (1987) in his attempt to define the profession of cartography.

On the other hand, the *Multilingual Dictionary of Technical Terms in Cartography* (Meyen, 1973) defines cartography as

> *Definition 3*
> The art, science and technology of making maps, together with their study as scientific documents and works of art. In this context maps may be regarded as including all types of maps, plans, charts and sections, three-dimensional models and globes representing the Earth or any celestial body at any scale (p. 1).

Dent (1985) uses this same definition of cartography which is "... broad enough in scope for most practitioners" (p. 5). He makes a distinction, however, between map making, which is defined by Muehrcke (1972) "as the aggregate of those individual and largely technical processes of data collection, cartographic design and construction (drafting, scribing, display), reproduction, *et cetera*, normally associated with the actual reproduction of maps" (p. 1), and cartography "which requires the study of the philosophical and theoretical bases of the rules for map making, including the study of map communication" (Dent, 1985, p. 5).

REMOTE SENSING

As with cartography, definitions of remote sensing abound in the literature (see Campbell, 1987; Fussell *et al.*, 1986). Indeed, almost all textbooks on the subject carry a definition of remote sensing, but overall there is some degree of agreement. Perhaps the most authoritative source on remote sensing is the *Manual of Remote Sensing* (Colwell, 1983), and there the definition given is

> *Definition 4*
> the gathering and processing of information about the earth's environment, particularly its natural and cultural resources, through the use of photographic and related data acquired from an aircraft or satellite (p. 1).

Fussell *et al.* (1986) review and compare a number of definitions. They conclude that remote sensing is a science, and that

> *Definition 5*
> in this search for a comprehensive definition (of remote sensing), some or perhaps all of the following elements need to be considered:
> - the noncontact acquiring, collecting or recording

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 55, No. 10, October 1989, pp. 1431-1434.

0099-1112/89/5510–1431$02.25/0

- from regions of the electromagnetic spectrum (typically although not exclusively) that include but exceed the visible region
- through the use of instruments
- located on mobile platforms
- and the symbolic transformation of collected data
- by means of interpretive techniques and/or computer-aided pattern recognition (p. 1510).

In his rejoinder, Curran (1987) takes issue merely with the identification of remote sensing as a science, preferring to have it labeled a technique, because researchers are not in pursuit of knowledge, but rather use remote sensing to solve problems.

Thus, remote sensing can be taken to include all activities from data collection (as long as the sensor used is not in contact with the object being analyzed, and where electromagnetic energy is used as a vehicle for the transfer of information), to preprocessing and image presentation. It has clear overlaps with the area of cartography, inasmuch as some of the definitions of cartography reviewed imply that that subject includes some or all of these activities.

Geographic Information Systems

The most recently recognized of the three fields under discussion is the much vaunted area of geographic information systems (GIS). As Crisman (1988) points out, the methodologies implemented in the computer environment of a GIS have a long pedigree (see Steinitz *et al.*, 1976). There have been a number of attempts to define a geographic information system, and two main themes can be distinguished: technological and problem-solving. The technological definition, typified by the following, concentrates on the computer-related aspects of the field, and has dominated the literature to date (Knapp and Rider, 1979; Marble and Peuquet, 1983; Curran, 1984; Marble, 1984; Parker, 1988):

> *Definition 6*
> Geographical Information Systems ... are a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986, p. 6).

More recent definitions have concentrated on the problem-solving aspect of a GIS. Thus, Goodchild (1985) gives the following definition:

> *Definition 7*
> A GIS is best defined as a system which uses a spatial data base to provide answers to queries of a geographical nature (p. 36),

which emphasizes the analytical nature of the systems. An emphasis on problem solving has been presented by Cowen (1987a; 1987b; 1988):

> *Definition 8*
> A GIS is ... a decision support system involving the integration of spatially referenced data in a problem solving environment (1988, p. 1554).

The definition of a GIS is not a closed case. Indeed, the first issue of the *Newsletter* of the Association of American Geographer's GIS Specialty Group included a forum on the definition of GIS (Mark, 1988).

RELATIONAL MODELS OF THE THREE FIELDS

From the preceding review, it is clear that the relationships among the fields are not well-defined. Three models are described here which outline possible conceptual relationships among the fields. These models are implied by the above definitions to be the most widely held approaches to defining the interactions of cartography, GIS, and remote sensing.

Linear Model

The linear model (Figure 1) depicts a situation in which the activities of remove sensing and GIS that were previously considered to be within the realm of cartography (Definitions 2 and 6) have emerged as separate and distinct areas. The evolution of technology has created a level of sophistication in each of these areas such that there are practitioners who considered themselves primarily involved in one or another. The nature of this model implies a temporal sequence of the activities wherein data acquisition (remote sensing) is followed by data management (GIS) and data presentation (cartography). Arguably, feedback does occur inasmuch as maps are digitized as input to GIS, for example.

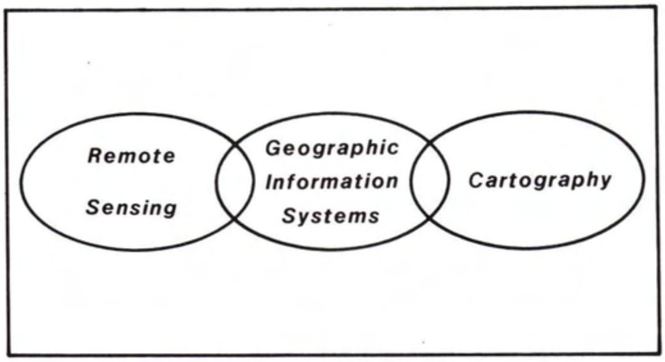

FIG. 1. The Linear Model of interaction depicts a situation where remote sensing feeds data to a GIS and the GIS passes it on to cartography for display.

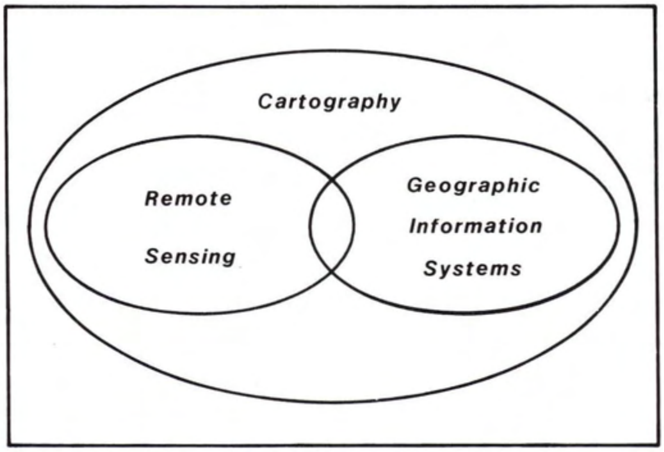

FIG. 2. The Cartography Dominant Model places cartography in an unrivaled position with respect to the other sub-disciplines.

Cartography Dominant Model

As is apparent from the definitions of cartography, data acquisition and data management have been included either explicitly (Definition 2) or implicitly (Definitions 1 and 3) as part of cartography. Previously, these aspects of cartography may have involved little more than paper and pencil as the hardware for data collection and manipulation, although computers are playing an increasing role. This leads to the formulation of a model in which the fields of remote sensing and GIS are encompassed by cartography (Figure 2). The overlap in the graphic representation of the remote sensing and GIS fields reflects their common concern of ordering acquired information in such a way that it may be effectively managed. The case for this model may be made when data are collected and manipulated to eventually be displayed as a map, the usual outcome of acquisition and manipulation of georeferenced data.

GIS Dominant Model

Similar to the cartography dominant model which is based upon definitions of that field in which remote sensing and GIS are contained, geographic information systems are described by Definition 6 in such a way as to circumscribe data collection, data management, and data display. The model in Figure 3 depicts this technological focus. The characteristics of the remotely sensed information in their relation to the ultimate display are represented by the overlap of the remote sensing and cartography symbols, but the preeminence of GIS in a fully automated situation is clear.

DISCUSSION

Critique

The three models discussed above, and formulated from existing definitions of the fields, either fail adequately to describe relationships between them or default to a position in which all spatial information-related concerns fall under the umbrella of either cartography or GIS. Exceptions to these situations can be shown. The linear model precludes an overlap of cartography and remote sensing, and so indicates that remote sensing information is only used in cartography when it is processed by a GIS. This is patently untrue in the case of analog products such as aerial photography for mapping, and may also be unrepresentative in the digital environment. Furthermore, the cartography dominant model does not provide for the possibility of an answer to a query of a spatial data base by a GIS which is not in graphic form, and the GIS dominant model subjugates the importance of what is often the final carrier of the communication, the map, to efficiency in management of the data. No one model accommodates all the definitions, and so an alternative is proposed.

Three-Way Interaction Model

The model illustrated in Figure 4 is presented as the most realistic representation of the interactions among the three fields as currently practiced. No field is placed in a position of dominance over the others, or indeed in isolation, but there is interaction in all possible combinations of the three.

Data acquisition and analysis are the emphasis in remote sensing. Within remote sensing, however, consideration must be given to the destination of the information gathered, which may either be used as an input to a GIS, or be presented in a graphic form. Furthermore, the computer systems used in modern digital image analysis have much in common with GIS processing, such that many vendors have, without changing data structures, implemented GIS functions in their image processing systems. Clearly, then, remote sensing does impinge on the domains that might otherwise be recognized as GIS and cartography, respectively.

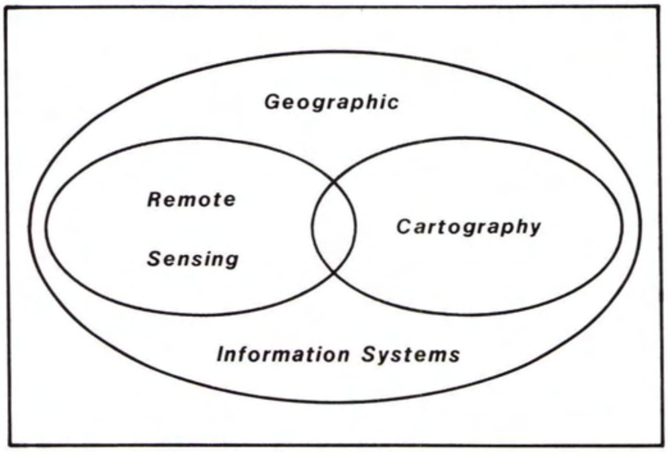

FIG. 3. The GIS Dominant Model suggests that the manipulation and analysis of information is all important in all sub-disciplines but, being a primary concern of GIS, gives that dominance.

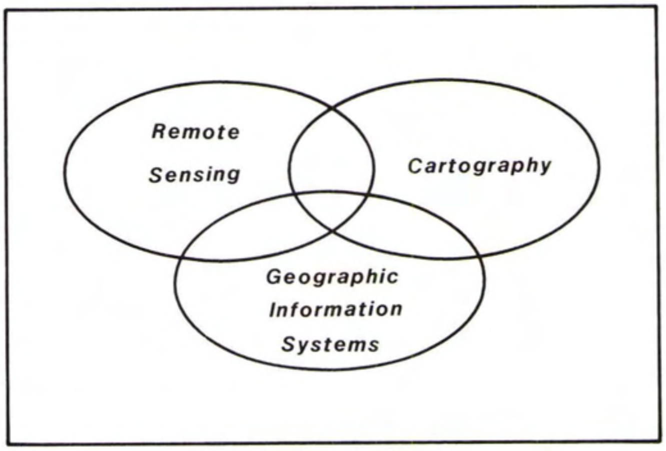

FIG. 4. The Model of Three-Way Interaction is that favored by the authors, where no sub-discipline dominates, but all are recognized as having unique if ovelapping areas of knowledge and intellectual activity

The analysis of geographic information to support decisions, which is the main concern of practitioners of GIS, is dependent on the way in which the data are gathered. When data are derived from remote sensing, quality and organization are dependent on expertise and methodology in that field. Similarly, while GIS professionals are not primarily concerned with the quality of the graphics that may be derived from the information, they should be cognizant of the implications of data manipulations upon the message presented in a resultant map. The cartographer may map information which is a direct product of remote sensing or which has been processed by a GIS. In this model, the emphasis within cartography is the effective presentation of the information as a map, and includes data analysis and manipulation when it is to facilitate that presentation.

The relationship of remote sensing and GIS with cartography in this model is not unlike the traditional view of data acquisition and data manipulation as precursors of the map. The three-way interaction model, however, depicts a relationship that recognizes these as fields which have evolved to a point that they are no longer subsidiaries of cartography. Remote sensing and GIS have a body of knowledge and require a level of expertise such that it is no longer realistic to envisage a cartographer as being expert in these areas as well.

Revised Definitions

An alternative model must be based on definitions of the fields which not only indicate breadth but also focus. Definitions which one may find acceptable individually need refinement when viewed in concert. The relationship of the fields requires not only that the definitions are reasonable but also that they reflect the nature of the interactions. A set of revised definitions is suggested:

> *Cartography* is the field which is involved with the graphic communication of spatial relationships and distributions, and includes

the analysis and manipulation of geographic data to enhance representation (from Definition 1).

Remote Sensing is the capture and interpretation of data from regions of the electromagnetic spectrum through the use of noncontact instruments, together with analysis and manipulation to facilitate interpretation (from Definition 5).

Geographic Information Systems are defined as the management, analysis, and manipulation of spatially referenced information in a problem-solving synthesis (Definitions 7 and 8).

Analysis and manipulation forms a common theme in these definitions. The methods used in each field do, however, differ. In cartography, manipulations such as projection change, line generalization, and analysis of data for deciding on choropleth map intervals are important. In remote sensing, analysis typically involves procedures such as cluster analysis (supervised or unsupervised) of reflectance values, and in GIS overlay analysis and zone buffering are typical analytical routines. This allocation of analytical methods to particular areas does not imply that those methods are not important to the other two. Map projections, for example, should be of concern to all areas, not the exclusive domain of cartography.

CONCLUSION

Four models portraying the interaction of cartography, remote sensing, and geographic information systems have been presented. The first three, *viz.* the Linear Model, and the Cartography and GIS Dominant Models, fail to recognize actual relationships or they involve the artificial preeminence of one field. The fourth model—three-way interaction—can be seen as recognizing the equal importance of each of the three fields, and accommodates existing interrelationships. While the authors prefer the Three-Way Interaction Model, readers may have alternative opinions, and debate as to the nature of the relationships among these fields is encouraged.

ACKNOWLEDGMENT

The authors wish to thank all the following for their constructive criticism and their encouragement: Barbara Buttenfield, Nick Chrisman, Mike DeMers, Ron Eastman, Duane Marble, and Jim Merchant. The opinions expressed, however, remain those of the authors at the time of writing.

REFERENCES

Burrough, P. A., 1986. *Principles of Geographical Information Systems for Land Resources Assessment*, Oxford University Press, New York, 193 p.

Campbell, J. B., 1987. *Introduction to Remote Sensing*, Guilford Press, New York, 551 p.

Carter, J. R., 1987. Defining cartography as a profession: *ACSM Bulletin*, August: 23–26.

Chrisman, N. R. 1988. Challenges for research in Geographic Information Systems. *Proceedings of the International Geographical Information Systems Symposium: The Research Agenda*, Association of American Geographers, Washington, D.C., pp. I-101-I-112.

Colwell, R. N. (ed.), 1983. *Manual of Remote Sensing*, 2nd Edition, American Society of Photogrammetry, Falls Church, Va., 2 Volumes, 2440 p.

Cowen, D., 1987a. Computer mapping vs. GIS: Implications for Applied Geography. *Papers and Proceedings of the Eleventh Applied Geography Conference*, Knoxville, Tn., pp. 43–51.

———, 1987b. GIS vs CAD vs DBMS: What are the differences. *Proceedings of the Second International International Workshop on Geographic Information Systems, GIS'87*, San Francisco, Ca., Vol. 1, pp. 46–56.

———, 1988. GIS versus CAD versus DBMS: What are the differences? *Photogrammetric Engineering and Remote Sensing* 54: 1551–1555.

Curran, P. J., 1984. Geographic information systems. *Area* 16: 153–158.

———, 1987. On defining remote sensing. *Photogrammetric Engineering and Remote Sensing*, 53: 305–306.

Dahlberg, R. E., and J. R. Jensen, 1986. Education for cartography and remote sensing in the service of an information society. *American Cartographer* 13: 51–71.

Dent, B. D., 1985. *Principles of Thematic Map Design*, Addison-Wesley, Reading, Mass., 398 p.

Fussell, J., D. Rundquist, and J. A. Harrington, 1986. On defining remote sensing. *Photogrammetric Engineering and Remote Sensing* 52: 1507–1511.

Goodchild, M. F., 1985. Geographic information systems in undergraduate geography: A contemporary dilemma. *The Operational Geographer* 8:34–38.

Henderson, F. M. (ed.), 1978. Remote Sensing and Cartography. *Remote Sensing of the Electro-Magnetic Spectrum* 5:1–65.

Knapp, E. M., and D. Rider, 1979. Automated geographic information systems and Landsat data: a survey. *Computer Mapping in Natural Resources and Environment*, Cambridge, Mass., pp. 57–68.

Lindenberg, R. E., and P. F. Fisher, 1988. Toward recognition of the functional distinctions among remote sensing, geographic information systems, and cartography. *Proceedings of the 1988 ACSM-ASPRS Fall Convention, ASPRS Technical Papers*, Virginia Beach, Va., pp. 151–159.

Marble, D. F., 1984. Geographic information systems: An overview. *Proceedings of Pecora IX, Spatial Information Technologies for Remote Sensing Today and Tomorrow*, Silver Spring, Md., pp. 18–24.

Marble, D. F., and D. J. Peuquet (eds.), 1983. Geographic information systems and remote sensing. *Manual of Remote Sensing*, 2nd Edition, American Society of Photogrammetry, Falls Church, Va., Vol. 1, pp. 923–958.

Mark, D., 1988. What is a GIS? In search of a definition. *GIS News*, Newsletter of the GIS Specialty Group of the Association of American Geographers 1:5–6.

Meyen, E. (ed.), 1973. *Multilingual Dictionary of Technical Terms in Cartography*, International Cartographic Association, Commission II, Franz Steiner Verlag, Wiesbaden, 573p.

Muehrcke, P. C., 1972. *Thematic Cartography*, Resource Paper 19, Association of American Geographers, Washington, D.C., 66 p.

Parker, H. D., 1988. The Unique Qualities of a Geographic Information System: A Commentary. *Photogrammetric Engineering and Remote Sensing* 54: 1547–1549.

Robinson, A. H., R. D. Sale, J. L. Morrison, and P. C. Muehrcke, 1985. *Elements of Cartography*, 5th Edition, Wiley, New York, 544 p.

Steinitz, C. F., P. Parker, and L. Jordan, 1976. Hand drawn overlays: Their history and prospective uses. *Landscape Architecture* 66:444–455.

(Received 6 December 1988; accepted 10 March 1989; revised 21 April 1989)