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# FORCING FUNCTIONS AND GEO-REFERENCED INFORMATION SYSTEMS

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## I. ABSTRACT

The geographical information system is viewed as a macro-system composed of a set of interlocking sub-systems. First, there is a conceptual system of ideas, which is then mapped onto a system whose components include data, hardware, and software. In the process the data are transformed into information which then becomes input for a planning system whose components include spatial and non-spatial models. This paper explicitly proposes the system concept of Forcing Functions as a key concept in G.I.S. planning, design and use. The implications of this approach for current issues such as the geo-coding alternatives, the selection of contents of a G.I.S., and the prospects for continuing viability in the context of technology transfer to developing countries, are then explored.

## II. INTRODUCTION

Each of the terms in the phrase "Geographical Information System" can be linked with a major field of specialization, each having its own body of theory. Systems Theory and Information Theory are well known. There is also the Theory and Philosophy of Geography as a spatial science (Chorley & Haggett, 1967; Bunge, 1962; Chung, 1981). The focus for this presentation will be on the G.I.S. as a functioning system, and the need for explicit consideration of the systems concept of "Forcing Functions" in the planning, design, and use of geographical information systems. The original title considered for this paper was a "Systems Approach to Geographical Information Systems." The title was dropped because it sounded rather tautological. Nonetheless it has the clear implication that the systems approach to geographical information systems has been neglected.

## III. THE CONCEPT OF "FORCING FUNCTIONS"

The source of the systems view used in this presentation is from Systems Biology, in particular the systems ecology school of thought centered at the University of Georgia. Bernard Patten (1971) writes:

Input signals to the system which originate in energy or information sources outside the system will be termed forcings. Such systems are forced dynamic systems, in contrast to unforced. (p.31)

By way of illustration, such a system may be viewed as analogous to a set of bathtubs with water flowing between them. Each bathtub would be a "state variable." The condition of the set of state variables at anytime would then be a function of the input rates and transfer rates for each state variable. Factors affecting the flow of water into this sub-system from the outside would be the forcing functions. Energy flow is the item of interest in the traditional eco-systems of the system biologists.

My own applied experience in systems modeling involved an attempt to model the economy of the island of Guam (Vail, Chung, and Schock, 1977). Dollar flow through the economy was the item of interest. The study found that the "forcing functions" concept played a decisive role in modeling the internal economic system. The island setting enabled us to clearly identify what was internal to the system and what impinged on it from the outside. Federal dollars, the Japanese tourist flow, and military expenditures, were important forcing functions affecting the internal dollar flow of the island's economy.

From this background it was easy to view the geographical information system process as a set of sub-systems in a macro-

system. However, it is operationally easier to view the G.I.S. as first originating as a conceptual System of Ideas. The traditional G.I.S. then becomes a transformation of this system of ideas into a system of information. This approach enables us to view the model as a flow of ideas, and thereby benefit from the analogous model of the systems biologist with his energy flow system. The forcing functions of this idea-system control the later input of the data to the geographical information system.

#### IV. IMPLICATIONS FOR CURRENT ISSUES

This section will examine the implications of the forcing function concept for selected contemporary issues in the planning, designing, implementation, and maintenance of the geographical information system on a self-sustaining basis.

A search for the forcing functions of the idea-system set seems logically to have sequential priority over the search for the forcing functions of the geographical information system set, which is in effect a product or surrogate of the idea-set.

The specific issues considered are:

- a) structured top-down approach to G.I.S. design
- b) the geocoding alternatives
- c) selection of input channels
- d) the human factor as a forcing function
- e) the viability of geographical information systems.

##### A. THE STRUCTURED TOP-DOWN APPROACH

The idea-system set is not a digital processing system, but a conceptual system. As such it may be an easier mode for communicating between the users, sponsors, and the G.I.S. designers. This perspective leads logically to the explicit consideration of the user or client perceived needs as a primary forcing function for the geographical information system. The perceptions of the sponsors and the system designers would also be forcing functions to be weighted and taken into account.

Experienced designers of G.I.S. have usually identified this consideration of user needs as an important first step in G.I.S. planning (Lindenlaub & Davis, 1978; Dangermond, 1979). The most recent theoretical and methodological literature on G.I.S. has also given high priority to clearly identifying objectives and user needs, based on acknowledged borrowings from the Management Information Systems literature (Johnson, 1981). Sinton (1978) however, concludes that the basic question

of who uses this data and for what purpose has rarely been studied in depth. The forcing function concept forces attention to the need for a clear operational consideration of objectives and user needs, and thus provides the basis for initiating a top-down structured approach to G.I.S. design (Yourdon, 1975).

##### B. ISSUE OF THE GEOCODING ALTERNATIVES

The literature is replete with examples of evaluation of data structures based on the source of data capture, the method of data capture, the kind of data storage, and the kind of storage for data-processing. Francois Bouille (1978) and David Mark's (1979) attempt to include the conceptual perception of the intrinsic properties of the phenomenon being investigated seems a rarity. The traditional focus on point, line and area properties of phenomena really refer only to pattern site traits of the phenomena, and are theoretically sterile points of departure for understanding the phenomena set as a spatial interacting process system (Chung, 1980a).

If the spatial information system is viewed as a whole system, it becomes clear that the spatial explanatory models into which the output will or should flow, has been neglected as an important forcing function for the data base organizational structure (Chung, 1980a; Madill, 1979; Aalders, 1980). This is a surprising discovery particularly since one of the classic prototype of spatial information systems developed by geographers at the Royal University of Lund, Sweden, explicitly considered the spatial analytical models into which the information would ultimately flow as an important consideration in data structure selection (Nordbeck, 1962; Nordbeck & Rysted, 1969, 1972).

The dichotomous issue of grid versus polygon geocoding alternatives may well be evaporating under the progress of the state of the arts. Moreover this dichotomy is vanishing not only from a technology improvement path (Bryand and Zobrist, 1976); but also from a programming algorithmic development pathway (Lowe, 1978; Teicholz, 1978; Nichols, 1979; Nagy & Wagle, 1979; Goodchild & Moy, 1976). Developments in raster compression combined with an end column format seem to hold much potential not only for raster data capture, raster storage, but also for direct raster processing (Miller, 1980; Zobrist, 1979). Clearly, the knowledge and perception of the state of the arts are forcing functions of importance in selecting geocoding structures for geographical information systems.

### C. SELECTION OF INPUT CHANNELS

Once the interaction system to be modeled has been conceptualized, the question may be raised as to which alternative data sets will match the ideas. In the pursuit of parsimony in the selection of input channels, one important forcing function is what I would like to call the potential algorithmic fertility of the data (Chung, 1980b).

Mark (1979) defined algorithmic relations as ones which are neither implicitly nor explicitly indicated, but which nevertheless may be discovered through an analysis of some or all of the data. Dangermond (1978) speaks of derived variables. Elevation is a good example of a terrain data item which is algorithmically fertile in the sense that many significant morphometric terrain relationships, such as relief amplitude and slope, may be derived from it (Evans, 1972; Verstappen, 1977).

### D. THE HUMAN FACTOR AS A FORCING FUNCTION

Many geographical information systems are essentially unbalanced, because the idea-system set focused on the environmental variables and excluded the human socio-economic system.

The human socio-economic system may be conceptualized as consisting of demand or consumption factors on the one hand and supply factors which provide for those demands. A land resource data base of information on soils, forest, terrain types, crops, etc., is really an information system about the supply of natural resource factors in the socio-economic system. Such an information system is inherently one-sided, if the supply is not related to the need or consumption side of the system (Calkins and Tomlinson, 1977; Paul, 1980; Chung, 1980b).

Data on demographics, labor force, income, transportation, and the quality of life (Morris, 1980), provide the basis for synthesis and evaluation of the merits of the data base as an interaction system. The resource concept has no meaning without people. The ability to objectively relate the land resource base to population distribution, and to evaluate the optimality of the spatial linkages between resources and population, are some of the benefits of including population and transportation in the data base. If the system cannot identify the people for whom it plans, then the plan alternatives may not mean anything to anyone except to the planners themselves (Berger, 1978).

### E. THE ISSUE OF VIABILITY

The literature is beginning to call attention to geographical information systems which seem to have failed, for whatever reasons (Johnson, 1981). In a developing economy it might well be necessary to identify show-case applications which will help provide the necessary climate for acceptance and perception of usefulness by the recipients. Considerations in selecting show-case applications involve not only identifying what sectors of the economy the local decision makers perceive as critical; but also which sector has been allocated the budget priority in their politically motivated budget plans. If the geographical information system can be designed to meet these needs along with the more long term academically justifiable needs, then the probability of self-sustained viability after withdrawal of outside funding might be enhanced.

Perhaps some conspicuous expenditures as so-labelled by the developmental economists, and so often decried by them, might actually have a show-case value, which may not be justifiable from a Western cost-benefit context; but might be very essential in a cultural value-benefit context. This line of thinking clearly points to the conclusion that the export of geographical information systems to other cultures should be preceded by a sound socio-economic, political, and environmental appraisal of the recipient culture area.

### V. CONCLUSIONS

The forcing function theme does not mean that previous geographical information system designers have not endorsed some or most of the views expressed here. For example, Bubenko (1980) in an excellent paper, separates the notion of the Conceptual Information Model from the Data Model. Bartolucci, Phillips and Davis (1980), Lechi-G and Zilioli (1980), and Paul (1979, 1980), have discussed the issues of cultural factors and problems of technology transfer to developing areas.

However, presenting these issues in the framework of the Forcing Function concept, provides an easily understood conceptual model from within systems theory itself, which if explicitly applied in geographical information systems planning, will certainly minimize the chance of overlooking key issues relevant to the viability of the proposed geographical information system.

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