USE ERROR: THE NEGLECTED ERROR COMPONENT

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ABSTRACT

Commonly recognized map errors include those associated with data collection (source error) and the processing of data for map compilation (process error). Another error component, use error is defined and added to this typology. This paper argues that without attention to use error, large investments to reduce source and process error may be wasted. Traditional representation of spatial information on paper maps has limited our ability to control this form of error in any significant way. While the misuse of maps cannot be entirely avoided, computer technology offers a possibility for limiting the opportunities for misuse. This idea is explored by examining ways in which maps are misused, and from this exploration, formulating geographic information system design strategies that may counteract the potential for use error.

INTRODUCTION

> "We must not forget that like carpenter's tools, maps should not be misused. More should not be expected of them than they can perform." (Wright 1942 p. 593).

Despite warnings such as Wright's, maps are often misused. We readily recognize misuse, but treat it as unavoidable. Map producers are not held directly accountable since they can have no certain knowledge of their audience or how their products will be utilized (Jenks and Caspall 1971). The conscientious producer attempts to control misuse by maintaining scrupulous quality control during production, and hopes that once the map goes out for distribution, it will be used in a reasonable manner. This can be a losing battle of larger investments in quality control with little or no assurances of reduction in misuse. The advent of geographic information systems has promised improvements in spatial data handling and analysis, but GIS has the potential to fall into the same trap; better quality control but no insurance against misuse. We cannot assume that GIS will automatically be less susceptible to misuse than traditional maps, and it may, in fact, exacerbate the problem by expanding access to mapped information.

Misuse of maps can have serious repercussions particularly when the end result is some legislative action. Efforts in quality control help indirectly, but misuse requires more direct attention. The development of GIS provides an opportunity to directly address misuse. Because users must interact with a system to use spatial data, a GIS can be consciously designed to avoid or minimize misuse. This paper provides a preliminary exploration of this idea. It examines the need for greater attention to the misuse of maps, explores the nature of map misuse, and considers strategies to avoid misuse through the design of GIS.

A TYPOLOGY OF MAP ERROR

This section considers the misuse of maps in the larger context of map error. Errors in maps can be contributed by any number of factors. Data collection is the first phase in which errors can be introduced and the term source error will used to describe these errors. Source errors can include errors in the positional description of the data or in the identification and discrimination (Chrisman 1982) of spatial objects. Limitations in data collection instruments, negligence on the part of the collector or instrument operator, adverse weather conditions, time constraints and other variables can contribute to the source error component. The cost of data collection and available funding, while not directly contributing to error, influences the precision, accuracy and completeness with which spatial information can be collected. The term source error, in this case, includes errors in completeness and positional and attribute descriptions introduced during data collection.

Manipulations of the data subsequent to collection, such as digital conversion, generalization, scale change, projections, and graphic representation can introduce additional errors. These errors will be referred to as process errors. In traditional map production, the occurance of process error generally ceases with the final compilation and publication of a map. In a digital environment, the potential for process error is always present since manipulations are easily carried out and each step potentially contributes new errors to the data.

In general, surveyors and cartographers share a concern for minimizing source and process errors. The analysis of errors in spatial data collection is a fundamental part of the surveying sciences, and cartographic training emphasizes faithful depiction of data in the transformation to map form. Conformance to professional standards, careful calibration of data collection instruments, and more accurate instruments may help to reduce source errors. In fact, we generally assume that these errors can be corrected by larger budget outlays, better instruments and more rigorous specifications of quality control. Likewise, increased precision and resolution in hardware devices, and quality control in software production are expected to reduce process errors.

Reductions in source and process errors improve the overall quality of a map and its usefulness. The correctness of a map, however, provides no quarantee that it will be correctly used. As Gersmehl (1981,1985) points out, the potential for error does not end with the compilation and publication of a map, but is attached to the very existance of a map and its use. The map itself is static (the published map accumulates no new source and process errors), but its existence and duration over time create the possiblity for use errors and an increased probability for errors with the passage of time. Use error in this case will refer to the misinterpretation of maps or the misapplication of maps in tasks for which they are not appropriate.

Use error is typically not recognized as a component of map error. Unlike the case of source and process errors, no professional group or discipline directly addresses use error. Also no formal training is assumed necessary for map use. As Keates (1982) suggests, many users would maintain that using a map requires no more than normal vision and average intelligence. Errors in map use, however, can carry significant penalties, since a single case of misuse can cancel all investments in source and process error reduction. Failure to consider use error in the past was excusable, but failure to consider it now risks many of the benefits we hope to achieve through GIS.

Misuse of maps has received little systematic study. We can point to specific cases of misuse, but we currently lack a comprehensive understanding of how and why maps are misused. Discovery of common characteristics in misuse can lead to a strategy for corrective action through GIS design. The next section examines cases of map misuse.

USE ERROR

Misuse of maps can occur in several ways. It is not possible to exhaustively document all instances of misuse, but a few examples help to illustrate the range of cases. Gersmehl (1985) cites an instance in which he compiled a dot map of histosols (organic soils) of the United States. Each dot was used to represent the general location and size of a histosol occurance, except three, which Gersmehl confesses to placing somewhat spuriously. This map appeared some years later reinterpreted as a map of Peatlands of the U.S. All of the dot locations, including the three spurious dots, were designated on the map as major peat deposits.

Two misuses of Gersmehl's histosol map are demonstrated by the Peatlands map. The dots, in two cases, were intended as generalized symbols of a few small, and widely scattered occurrances of histosols. On the Peatlands map these were depicted as sizeable peat deposits corresponding with the locations of the original dots. The other misinterpretation was that all histosols were assumed to be peat deposits, (not a correct assumption). This fact was, of course, well known to Gersmehl, but was nowhere communicated on the map.

We can identify at least two generic causes for these cases of misuse: lack of information and divergence from convention or expectation. Physical space limitations and graphic conventions restrict the amount of information which can be shown on a map. Gersmehl's choice of scale limited his ability to present a more complete description of the information. If additional attributes of each histosol type had been included, such as its peat potential, the error might have been avoided. His choice of scale also forced him to sacrifice positional accuracy for graphic emphasis, an instance of cartographic license which lead to nasty repurcussions. If users have certain expectations about mapped information, then violations of these can result in errors. Many users assume that the location of an object on a map bears some relationship to the object's true position on the ground. Gersmehl, because of cartographic license in placement of a dot on a map, violated the assumption and introduced the possibilty for error.

The Gersmehl case also illustrates that misuse frequently occurs when maps compiled for one purpose are used for other purposes for which they are not suitable. This can happen for a number of reasons; some intentional and some not. Time and budget constraints are common culprits in these cases. Such constraints can prevent the acquisition of appropriate data for the intended use and force the use of available but inappropriate data. In another example, Napton and Luther (1981) note the misuse of generalized soil productivity maps. The productivity maps were created by aggregating soils data into categories based on yields of corn per acre. To simplify the spatial complexity of the maps, several small adjacent but dissimilar soil map units were combined to create larger productivity units which could be represented at a smaller scale. The final maps did not in any way document the presence, size, shape, quality or location of soils within productivity units which had quite dissimilar productivity levels. Based on comparison with detailed information, the generalized maps were determined to have twenty three percent error in misclassification.

Although these maps were only compiled for very general planning purposes, their concise form promoted their subsequent use for prime farmland designation, zoning administration, and tax assessment. In these cases, the generalized productivity maps became the basis for legislative action with implications for individual property rights and taxes. As Napton and Luther state:

> "Maps with this amount of error might be helpful for some purposes, but the existence of the map invites use for many other purposes, ... the employment of this information for local or site specific planning opens the door for court challenge." (1981 p. 178)

This problem can be compounded in the case of digital files. Since digital files are still time consuming to create, uses of existing files can be overextended. Blakemore (1985) describes a file of British districts digitized by the Department of the Environment as a thematic base for choropleth mapping. The file had no information on the accuracy of the coastline or internal positional accuracy, yet it was used and misused for many different purposes simply because it was readily available in digital form. Many early digital files were generated from small scale maps since these could be converted most quickly and required the least storage. These maps have limited use for detailed analysis, yet the temptation to use these files remains since they are available.

Legislative mandates can be particularly guilty in this respect by setting timelines which make collection of the appropriate data impossible. In order to meet legislative requirements, any available data is used whether it is suitable or not. The State of Maine recently passed comprehensive planning legislation which illustrates this problem. The legislation requires communities to develop comprehensive plans and subsequent zoning ordinances or other enforcement mechanisms by as early as 1991. Information at a level of detail sufficient to develop adequate and defensible plans is not currently available, nor likely to be by the legislative deadline. The potential for misuse of existing information is therefore substantial.

There are many opportunites for misuse of available data. Misuse can occur if the available data is out of date, if the scale or resolution of the data is too coarse for the intended application, or if the classification and interpretation of the available data does not support the intended application. In many of these cases we can point to misuse of generalized maps as a common error. Generalized maps are particularly troublesome because they are more restrictive of information and users are often unaware of how much information has been lost. Generalized maps are usually not accompanied by information on the source material, classification and interpretations made during generalization, and the degree of generalization. Without this information, users can quite easily use the data for purposes not originally intended.

Other instances of use errors occur when maps are used for quantitative analysis without recognizing the effects of map scale, conventions, or data type. Measures of point location, of length, area and count vary with changes in scale. Several mathematicians and cartographers have discussed the difficulties of making reliable quantitative measures of phenomema from maps (Steinhaus 1954, Richardson 1961, Maling 1968, Perkal 1966). Boesch and Kishimoto (1966) also cite the difficulties of making reliable counts of objects from maps. Using maps to make counts of objects leads to errors if the completeness and currency of the maps have not been accounted for. Making counts from complex maps is also a case in which visual processing is not efficient. Often the level of measurement (Stevens 1946) of the data represented on maps is not accounted for in analytical use of maps. Hopkins (1977) points to the addition of ordinal valued maps as a common error in suitability analysis. Others have presented the errors associated with the overlay of maps for planning purposes (MacDougall 1975, Chrisman 1982, 1987).

The above examples describe cases in which maps were an appropriate representation medium for information, but were inappropriately used. A different case of misuse arises when a map itself is the wrong medium for presenting information. An example of this misuse is illustrated in Zinn v. State of Wisconsin. A hearing examiner highlighted a contour on a USGS quadrangle map to indicate legal evidence of the ordinary high water mark (OHWM). Land below the ordinary high water mark belongs to the state. Based on the map evidence an owner of land abutting the lake aasserted that the state had claimed most of her property, created a cloud on the title to her land, and deprived her of her ripariarn rights to the lake. Epstein and Roitman (1987) suggest that the graphic depiction of the OHWM on the map provoked the legal conflict. A direct statement that the OHWM existed at elevation 990 would have been preferable. Presentation of the information in this manner would have avoided the misinterpreatation resulting from the graphic depiction and possibly avoided the conflict.

From these examles we can identify several common causes for map misuse which can be summarized as follows:

• Lack of information.

• Deviation from conventions and expectations

• The use of small scale, generalized maps for many uses because they are convenient and less expensive.

• The lack of current data and ability to make frequent updates.

• A lack of documentation on data quality

The presentation of spatial information in map form demands data reduction. Early computer systems also suffered from limited storage capabilibity. Decreases in the cost of digital storage and increases in the speed of digital processing remove some of these barriers. Advances in digital mapping will now allow greater control over use error than existed with paper map production. The next section suggests that some of the generic cases of map misuse can be avoided or mitigated by specifically designing systems and databases to avoid them.

RECOMMENDATIONS FOR CONTROLLING USE ERROR

The above examples indicate that omission of information due to physical constraints, generalization, lack of currency, and lack of quality documentation are primary contributors to use errors. Recognition of these as common contributors to misuse can lead to solutions. Without attempting to predict the potential misuse of different spatial data sets, we can nevertheless quard against the possibility by improving spatial information management through GIS design. Some directions for system design which show promise include:

The ability to store more information than was previously allowed by physical map sheet size.
Often much more information is collected during inventory than is passed on to eventual users. This restriction on dissemination of information has been due to the physical limits of the paper map. Early computer systems were restricted by limited storage space, but such limitations are rapidly disappearing. A digital data base can now be structured to store more information for access by users.

Representation of more detailed, disaggregate data
Generalized maps have been subjected to summaries, aggregations and other reductions of information for specific purposes. Detailed, disaggregate data would give users the flexibility to aggregate the data for their specific needs. Users would not be constrained by previous summaries or interpretations (aside from potential biases in data collection) which could impact their questions. Any generalization or aggregation of the detailed data requested by users should be documented so that the extent and location of data modifications would be available to subsequent users.

Potential for more extensive data quality documentation
Paper maps may include reliability diagrams or other sketchy information on data quality. Digital databases provide the potential to associate quality information with individual objects and their descriptions. As an example, Dutton's (1983) GEM structure can represent positional accuracy by the depth with which an element is placed within the structure.

Improvements in updates to maintain currency
Paper maps are often out of date because publication costs limit frequent reissues. Use of out of date maps lead to errors. Digital databases have the potential to support more frequent updates although real time transactions on spatial data have not been perfected. Data documentation should specifically include information on currency.

Structuring data to avoid illegal or illogical operations
Certain mathematical operation are only valid for certain levels of information. For example addition and subtraction of nominal or ordinal valued data is meaningless. Databases can be structured so only valid operations can be applied to particular data types. A database might also be designed to detect when the resolution of the data is insufficient for a particular application.

CONCLUSION

Although misuse of maps in the context of paper maps was an insoluable problem, developments in GIS have the potential to overcome many cases of misuse. If we are to reap the full benefits of GIS, we should not overlook this opportunity to include use error in overall plans for improved quality control.

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