

# APPROACHES TO TRUTH IN GEOGRAPHIC VISUALIZATION

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## ABSTRACT

This paper addresses two related issues: how we can judge and represent 'truth' in the context of Geographic Visualization (GVIS) and what 'truth' is in this context. The first issue is approached from an analytical perspective, with emphasis on measurable aspects of validity in geo-referenced information and on representational methods for depicting validity. In relation to the second issue, a philosophical perspective on truth emphasizes the concept of *cognitive gravity* as a factor that leads scientists and policy makers to see only what they expect to see. The goal of this essay is not to provide specific guidelines for dealing with aspects of truth in GVIS, but to introduce a framework for exploring the relevant issues. The framework proposed is grounded in a semiotics of geographic representation.

## INTRODUCTION

Truth of spatial information, and of decisions based on that information, is a significant issue for both scientific research and policy formulation. As we enter an era in which visual evidence is gaining (regaining?) prominence (due to technological advances associated with scientific visualization and multimedia), we should take a critical look at the implications of our visual tools. Geographic visualization systems (particularly when linked to GIS) provide powerful prompts toward insight by scientists and serve as facilitators of policy decisions by a range of analysts, resource managers, planners and others. Most GVIS research thus far has focused on getting new tools into the hands of potential users (for example, see: Dorling, 1994; Kraak, 1994; Asche and Herrmann, 1994). It is time that we begin to give some attention to the implications of those tools. These implications are integrally related to the truth of the representations that GVIS provides and to the truth of mental visualizations that it generates. Scientists and policy makers will inevitably make judgements about GVIS truth. At this point, we are just beginning to understand the range of technical and social factors that have an impact on these judgements – and the ways in which these judgements influence scientific thinking and public policy.

A discussion of truth in GVIS must begin with an understanding of GVIS itself. Visualization is a concept with a variety of meanings and the addition of "geographic" as a prefix does not necessarily clarify things. Elsewhere, I

have defined GVIS in terms of map use – in contrast to other definitions that have focused on the technology that underlies visualization (MacEachren, 1994). The emphasis of this use-based characterization is on the nature of interaction between users and visualization tools. I see visualization and communication as occupying two corners of a three-dimensional visual tool use space (defined by three axes: public-private, high-interaction – low-interaction, seeking unknowns–accessing knowns). Within this tool use space, I argue that the prototypical examples of geographic visualization are those that combine relatively private use of maps (and other spatially-referenced displays), a goal of seeking unknowns in a set of information, and a process that is highly interactive. It is in the context of scientific exploration and the search for unknowns that issues of truth are particularly complex and problematic. How, for example, are we to judge the truth of a science based increasingly on visual evidence for which we have no standards of truth?

Within the realm of highly interactive use of visual tools as potential prompts to insight, issues of truth can profitably be addressed from the perspective of *semiotics* – the science of “signs.” Signs are relations among a *referent* (an entity in the world), a *sign-vehicle* (a representation that stands for that entity), and an *interpretant* (the shared meaning that links the two) (figure 1). As such, signs exist at multiple levels in a visualization context. Each individual mark on a display can be the visible component of a sign relation (i.e., the sign-vehicle), groups of these marks can be seen as a whole forming the visual part of a higher order relation (a compound sign-vehicle), while entire displays can “stand for” complex entities (referents) and the concepts (interpretants) they are associated with.

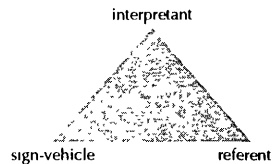


Figure 1. A triadic model of sign relations

Starting from this semiotic base, truth in GVIS can be approached from two perspectives. The first is an analytical one that equates “truth” with validity of the sign relations. From this perspective, the possibility for truth is assumed, and the goal becomes that of increasing the chance for valid signs by making more reliable displays, by measuring and representing display reliability, and by developing display forms that decrease the potential for interpretation error. The second perspective from which GVIS truth can be approached is a conceptual or philosophical one in which the very notion of truth is questioned. The goal is to explicate the standards against which truth of sign relations might be judged.

### ANALYTICAL APPROACHES TO “TRUTH” IN GVIS

In practice, the concept of truth is often simplified to one of validity (or reliability). From the semiotic perspective described above, this restricted view of truth has two subcomponents. First, validity can be assessed in terms of the direct sign-vehicle to referent link (dealing with what is

referred to as the *semantics* of the sign) (figure 2a). Second, validity can be assessed in relation to the indirect link through the interpretant (i.e., *sign pragmatics*) (figure 2b). In the first case, sign-vehicle validity is defined in relation to the reliability with which sign-vehicles and referents are matched (e.g., how certain can we be that a location on a 100 inch isohyet received 100 inches of precipitation). In the second case, interpretant validity is relative to the meaning we attach to the sign relation, thus putting emphasis on the cognitive models and knowledge that the user brings to the GIS environment.

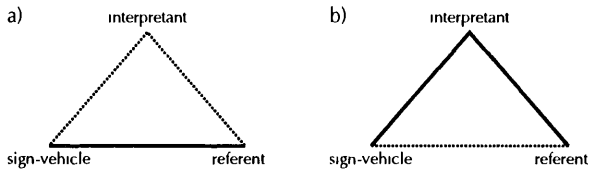


Figure 2. The emphasis of semantics (a) is on the sign-vehicle to referent link. That of pragmatics (b) is on the link through the interpretant.

#### *GIS semantics – sign-vehicle validity*

A semantics of GIS should address three components of sign-vehicle validity, that associated with data quality, that associated with the representation form, and that associated with the representation process (i.e., how data are manipulated in order to allow a particular representation form to be applied). Validity issues associated with representation form involve the selection of “data models” through which data (generally treated as referents) are signified. Validity issues associated with the representation process center on assumptions that underlie that process and on the analysis of what has been called “method produced error” inherent in spatial data processing.

The data quality component can, perhaps, be addressed most effectively through direct representation of reliability estimates (assuming, of course, that such estimates can be derived). As digital data begin to comply with the Spatial Data Transfer Standard (FIPS 173), reliability assessments should become a more common component of digital spatial data. On the assumption that reliability information will begin to accompany most data sets, considerable attention has been directed to developing appropriate representation methods. Among the issues addressed are: symbolization (i.e., sign-vehicle) schemes for signifying data reliability (MacEachren, 1992; McGranaghan, 1993; Fisher, 1994a), the “syntactics” (or internal logic) of sign-vehicle sets designed to include data and reliability on the same map (van der Wel, et al., 1994), user interface styles for depicting data reliability (MacEachren, et al., 1993), and impediments to representing data quality (i.e., reliability) (Buttenfield, 1993).

Issues of data model validity (and validity of sign-vehicles associated with those data models) are perhaps best dealt with through the use of multiple representations. Jenks (1967) brought attention to the range of interpretations that might be generated due to data model choice. In relation to GVIS, MacEachren and Ganter (1990, p. 78) suggested that visualization systems should "... permit, perhaps even demand that the user experience data in a variety of modes." Pointing to the advances in technology that make production of multiple representations easy, Monmonier (1991) has taken this idea one step farther by suggesting that our past approach of providing the single "optimal" map should now be considered unethical.

In most exploratory GVIS applications, the representation process has an influence on what can be seen in the display (comparable to that of data model choice). Research on method produced error has demonstrated systematic differences in representations resulting from different methods of interpolation (Morrison, 1971), generalization (McMaster, 1987), classification (Coulson, 1987), etc. With some data manipulation procedures, such as kriging, reliability estimates are part of the result. In these cases, method produced uncertainty can be treated in the same ways as uncertainty in data quality (i.e., using the range of representational techniques mentioned above). An alternative is to adopt the multiple representation approach. This use of multiple displays as a method for signifying spatial reliability has been advocated by Goodchild et al. (1994), and by Fisher (1994b). In the former application, the multiple views are based on a set of side-by-side static representations – with reliability signified by similarity at each location from view to view. In the latter case, a single view is changed dynamically – with stability over time being the sign-vehicle for reliability.

#### *GVIS pragmatics – interpretant validity*

A pragmatics of GVIS should address validity of interpretations arrived at through use of visualization tools. Pragmatics deals with the sign-vehicle to interpretant link and puts emphasis on the "meaning" embedded in and brought to the sign. The distinction being made here is between a sign's *denotation* and its *connotation*. A sign's denotation is its explicit meaning; that meaning embedded in the display through the cartographic rules used in display creation (e.g., dark red = warm temperatures and dark blue = cool temperatures). Connotations are the implicit meanings brought to interpretation, meanings that may or may not be anticipated by the person making decisions about the display design (e.g., on a temperature map in which red = warm and blue = cool, the break between blues and reds might be assumed to be meaningful, perhaps a representation of the freezing point).

In considering GVIS denotative meaning, an analogy can be made to statistical analysis. Interpretation of a geographic representation is analogous to statistical hypothesis testing. Interpretations based on visual evidence have a potential for two kinds of error: *seeing wrong* (equivalent to a Type I statistical error) and *not seeing* (equivalent to a Type II error)

(MacEachren and Ganter, 1990). As with the statistical counterparts, the likelihood of Type I and II visualization errors is a function of the degree to which the display is a representative “sample” of possible world views, and of the standards applied for acceptance or rejection of what is seen.

‘Seeing wrong’ occurs when a sign relation is formed using inappropriate links among the three sign components (e.g., when a sign-vehicle is incorrectly matched to referent and/or interpretant) (figure 3). One common GVIS example involves interpretation of coincidence in space as evidence for functional association.

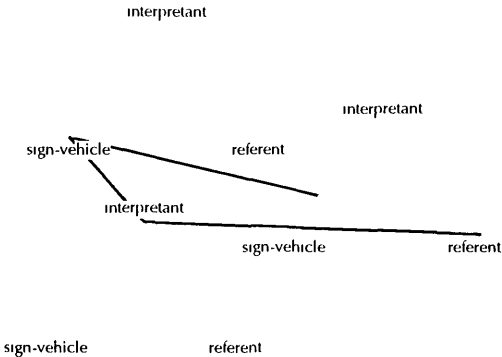


Figure 3. ‘seeing wrong’ – incorrect links among sign components.

‘Not seeing’ results when signs are not recognized as such or when sign relations are incomplete (figure 4). In this case there is a failure to recognize a particular component of the display as a sign-vehicle, or a failure to identify the required links to complete the sign relation. With GVIS, such failures are likely to result from a failure to recognize spatial association among subordinate sign-vehicles.

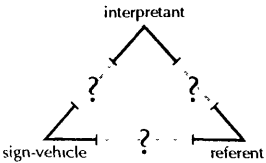


Figure 4. ‘not seeing’ – a failure to achieve sign component links

There is an obvious standard against which to assess denotative meaning, although it is perhaps difficult to measure. With connotations, however, there is no such standard. Since connotation is ‘brought to’ the interpretation by the individual, rather than being embedded within the sign relation, there can be no single judgement about the truth of connotative meaning. Connotation associated with GVIS (or other) signs derives from an individual’s complex mix of life experience and specialized knowledge. Although connotation is established at an individual level, however, shared life experience leads to some level of shared connotations. Among the most important in relation to issues of truth in GVIS is a *connotation of veracity*, a tendency to assume that ‘if it shows up on a map it must be true’ (MacEachren, 1995).

## TRUTH – BY WHAT STANDARD?

A fundamental flaw in any effort to objectify truth in visualization (or science in general) is that our only standard for truth is what we (science and society) believe to be true – defined by the paradigm within which we are working. Even if we ignore, for the moment, connotative meaning, judgements of “truth” in the semantic and pragmatic components of GVIS must be made against this rather unstable standard. As paradigms change, “scientific truth” also changes.

The strong tendency to believe in established doctrine, and to discount evidence that does not fit the expectations derived from that doctrine, has been pointed to by a number of authors, most notably Kuhn (1970). De Mey (1992) recently introduced the term *cognitive gravity* as a label for the “momentous strength of established conceptual systems.” Cognitive gravity can be defined as the pull toward a particular interpretation exerted by the large volume of accumulated facts and rules – and is illustrated by the often strenuous resistance to new ideas (e.g., Copernicus’ helio-centric view of the solar system, continental drift, etc.).

To a large extent, cognitive gravity (and its associated regularized patterns of thought) is precisely why science works, and why GVIS tools are so powerful. GVIS facilitates application of our repertoire of learned patterns. These patterns are both visual ones (related to matching what we might see in a display with what we have seen before) and conceptual ones (related to the sequence of views we might elect to look at or the relations we might attempt to find). Applications of these patterns provides the mechanism through which interpretants become part of sign relations.

Using accepted concepts as our gage against which to measure truth, however, has potential negative consequences, particularly in the context of visualization, with its emphasis on a search for unknowns. When the goal is largely that of using the power of vision to let us notice the unusual in an effort to prompt insight, a tendency to disregard the unusual can be a serious impediment to scientific advances.

A consequential example of cognitive gravity associated with visual geographic evidence is provided by the recent discovery of the ozone hole. Initially, the key pattern was not seen in the accepted evidence – NASA produced image-maps from the total ozone mapping spectrometer. Joseph Farman, a British atmospheric scientist was the first to *notice* the ozone hole – because he did not rely exclusively on the visual evidence provided by NASA images (Hall, 1992). For Farman to believe that he had discovered something significant, he had to overcome the “cognitive gravity” of which those images were a part.

Farman was part of a British team that had sensors on the ground. These sensors registered extremely low levels of ozone. The research team initially doubted the measurements (because they did not agree with the images

derived by NASA, nor with the assumptions underlying them). Farman and his team checked results by adding a second ground sensor, and after waiting a full year to compare results, the low numbers were finally believed. The paper describing Farman's findings was submitted to *Nature*, where it received the following comment from one reviewer:

This is impossible! But of course if it's true, we can't wait twenty years to find out that it's true, so publish immediately! (Hall, 1992)

Cognitive gravity nearly prompted the reviewer to discount Farman's evidence in favor of the more compelling and scientifically accepted image maps. It is ironic that maps both delayed discovery of the ozone hole and hastened its acceptance by the general public. The delay resulted because data analysts at NASA decided to 'flag' (and exclude from the images produced) data values that were lower than computer models had predicted – thus only displaying results that were within predetermined expectations. Farman's simple graphs are what ultimately convinced scientists – but the revised digitally produced map (with its connotations of veracity) is what convinced the public.

The tendency to accept what fits our expectations and reject what does not – something that has been called a confirmatory bias – is often coupled with a failure to remember the “respects of similarity” with which representations are linked to the world (i.e., a failure to apply the appropriate interpretant to the sign relation).<sup>\*</sup> Lakoff (1987), for example, contends that chemists analyzing representations produced with a Nuclear Magnetic Resonance device, have come to treat the images as real. Restated in terms of the semiotic framework presented here, the chemists Lakoff refers to seem to treat the sign-vehicle as similar to the referent in *all* respects. It is clear from explanations that accompany isarithmic maps in many earth science and geographic journals that climatologists treat isolines, and their precise position, as equally real. Isolines are assumed to signify not only values at locations, but shape and structure of the underlying phenomenon. GIS toolkits now allow scientists to use “focusing” to highlight particular isolines and study their position relative to the depiction of a second or third variable (see DiBiase, et al., 1994). We have little conception, however, of the standard that should be applied to judging truth of the interpretations derived.

## DISCUSSION

As visual evidence (often facilitated by cartographic tools) becomes increasingly central to the way in which scientists and policy analysts think, we must become increasingly critical of that evidence. The inclusion of data quality specifications in the Spatial Data Transfer Standards, the NCGIA Initiative on Visualization of Data Quality, the efforts by the National Center for Health Statistics to incorporate reliability information in some of their

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<sup>\*</sup> see Giere (1988) for a discussion of the “respects of similarity” by which scientific models are linked to the world they “represent.”

maps, are all steps in the right direction. Truth in GVIS, however, is more than an issue of data quality or representation reliability. It goes to the heart of the assumptions we make about how the world works and about what is represented in our visual displays. We can devise no absolute measure of truth in GVIS. Truth can only be defined relative to the models or paradigms within which we decide what to represent and how to represent it. If we are interested in issues of truth, we must give as much attention to the implications of these paradigms as we do to the measurement and depiction of validity (as it is judged against a standard determined by the paradigms).

A tradition of critical analysis is developing within cartography. At this point, however, most of the attention of this critique has been directed to the 'communication' corner of my visual tool use-space. Significant contemporary public images such as highway maps (Wood and Fells, 1986) and the Van Sant image-map (Wood, 1992) have been "deconstructed," as have a variety of historical maps and national mapping programs (Harley, 1987; Edney, 1994). Little attention has yet been given to critical analysis of the geographic representations that are becoming increasingly integral to early stages of the research process (see Krygier, 1994 for one such attempt). As the role of cartographers evolves from that of mapmakers (with emphasis on presentation graphics) to that of geo-information facilitators (with emphasis on building tools for interactive data exploration), it is time to take a closer look at the basis for the information we facilitate and at the interaction between the visual display tools we design and the research paradigms they are meant to work within – or break free of.

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