GeoVisualization, GIS and Design

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By way of a 'position paper' I offer some loosely related musings on **Design** and **GIS.** These come from the research 'design space' between GIScience, Cartography and Information Visualization that I and colleagues at the **giCentre** have been exploring recently in our **geovisualization** research.

The more we do so, the more I am persuaded that geovisualization and Design are closely related, but perhaps not in the manner postulated in the SCGD 'central question.' The former is highly dependent upon the latter in my experience. More broadly, I would argue that fundamental concepts of Design are very relevant to enquiry-based GIS and are important in supporting spatial thinking, enabling geovisualization and so developing a curriculum that promotes spatial thinking relies upon relationships between Design and GIS.

Concepts such as similarity, quantity, category, hierarchy, proximity and relatedness amongst large numbers of objects of study that vary over space and time can be effectively represented graphically to aid spatial thinking. Geovisualization research develops cognitively plausible combinations of layout, symbolism and interaction according to data, task and user(s) that enable data analysts to mutually assimilate such relationships effectively and understand spatial processes . . . and generates knowledge that supports this process.

As geovisualization is design led I have not been able to resist focusing on design issues here . . .

1. Cartography is Design: But is GIS *Still* Hidebound by the Cartographic Legacy . . .?

Design "implies a conscious effort to create something that is both functional and aesthetically pleasing"[1]. The **design process** is essential in considering the way in which functionality, aesthetics and constraints are managed in the designed 'thing'. Cartographers know the importance of design, as stressed by Arthur H. Robinson, and have established principles that guide the map design process. GIS uses some of this knowledge, but Fisher (1998) contended that GI Systems were 'hidebound' by the traditional role of the map as data collection and storage device. He argued that GI Systems should be more flexible analytical tools designed to make sense of information and foster insight and that effective visual design was vital:

> "GIS must change to support real geographical information as it is recorded by domain scientists, and software tools need to be developed to transform that data into intelligible views and exploratory tools . . . With this change the need for cartographic design skills among GIS users will increase rather than decrease. To ensure that geographic information will be intelligible to the investigator and the user 'good' design will be paramount, and is currently noticeable by its absence in system defaults available within GIS." (Fisher, 1998)

The functional nature of early GI Systems may have dominated over aesthetics in design. Liddle (in Moggridge, 2007) indicates that this is typical of technologies as they are increasingly adopted by enthusiasts, then professionals and ultimately a wide base if consumers. But how much have things changed in the last 10 years? To what extent are we designing for *exploration* in GIS? In geovisualization and visualization more generally highly interactive maps and graphics are designed to support this process––to encourage spatial thinking and act as prompts for insight.

[1] The obligatory Wikipedia entry - 'Design: 30/11/08'

2. Layout : A Space-Filling Trends in Visual Design for Exploration

Layout is an important aspect of design in cartography and information visualization––which have different spatial constraints. Methods that use space efficiently to make large quantities of data 'intelligible to the investigator' are being developed and deployed in information visualization. There is a notable trend for data dense graphics to fill screen space at the expense of functional interface elements. Spatial information is being used in this way. For example Cui et al. (2008) use edge clustering methods to coherently map migration flows between 1,790 locations in the US with nearly 10,000 edges in a manner that is functional and aesthetically pleasing. The results are stunning: "the patterns are beautifully revealed." GI Scientists are contributing to these efforts. Skupin & Fabrikant (2003) report methods for transforming non-spatial data into designs that 'map' information. They apply cartographic principles to these layouts to make them intelligible. We have recently augmented space-filling layouts of trees with spatial information (Wood & Dykes, 2008) and used these in the exploratory analysis of large multifaceted data sets (Slingsby et al., 2008).

These methods have promise, and show trends that address Fisher's concern––but how do we know what is 'good' layout or 'good' design?

3. Aesthetics: Increasingly are Important (and popular) in Information Visualization

Studies such as that of Cawthon & Vande Moere (2007) may provide some answers. Aesthetics are considered an important factor in making data intelligible in information visualization and research shows that the aesthetic quality of a graphical design can affect their usability (Cawthon & Vande Moere, 2007). The visual emphasis on data rather than functionality reported above may thus have a positive effect on the use of graphics as well as visual quality.

Can we evaluate aesthetics? Kosara (2007) argues for a critical approach to considering aesthetics. He proposes that visualization criticism be adopted by the academic community and suggests a process through which this may be achieved. Doing so may enable us to of evaluate aesthetics in visualization and develop building blocks for a theory of visualization to guide design.

4. Animation: Transitions Have Aesthetic Quality?

Certain aspects of design seem to have a substantial positive aesthetic effect. 'Animated transitions' are increasingly popular in information visualization (e.g., Wattenberg, 2005; Rosling et al., 2004). Research also suggests that they can be effective (Heer & Robertson, 2007; Robertson et al., 2008). GI Scientists have considerable experience in modelling and representing temporal phenomena. Their knowledge of and experience in developing animated cartographic designs may provide some pointers for those experimenting with transitions.

Perhaps GI Systems should use space-filling layouts and animated transitions to improve the aesthetic quality of their graphic design and lessen the focus on functionality as they are an increasingly consumed technology?

5. Interaction: A Multitude of Possibilities – with Scope for Spatial Behaviours

In addition to layout, interaction with visual designs is key to the acquisition of ideas and knowledge from them. The way that something behaves requires informed design to ensure that it is functional and aesthetically pleasing. As is the case with layout and symbolism, the effects and qualities of interaction must be fit for purpose and appropriate to context. Moggridge (2007) describes interaction design as being :

> "concerned with subjective and qualitative values [and starting] . . . from the needs and desires of the people who use a product or service, and strive[ing] to create designs that . . . give aesthetic pleasure as well as lasting satisfaction and enjoyment" (Moggridge, 2007)

The information visualization literature provides some guidance here. Yi et al. (2007) present a typology of interactions that may help designers navigate through the vast possible solution space. Heer & Agrawala (2006) encode information visualization design knowledge in software design patterns that can be adopted and / or developed. Ongoing work is establishing the extent to which these approaches are applicable to GI Science, but we have recently proposed geographically weighted interactions and presented these to the information visualization community (Dykes & Brunsdon, 2007).

6. Evaluation: It's Difficult to do Geovisualization Evaluation Well!

How do we know what is 'good' design in our interactive, animated maps and graphics for geovisualization? Quantitative methods from Human Computer Interaction Design may provide some solutions. But, if our maps are not hidebound by the cartographic legacy then solutions will be uniquely designed for specific users and precise tasks. In this context design evaluation needs to be more qualitative in nature and should involve users throughout the ongoing development process in which requirements are likely to change as needs develop and possibilities are discovered and augmented. There are trends in this direction in information visualization––Shneiderman & Plaisant (2006) propose the MILC approach that uses multi-dimensional in-depth long-term case studies.

Visualization design evaluation is likely to be increasingly ethnographic as a result. Should geographers and social scientists not be particularly good at this . . .?

As visualization design and evaluation are so intertwined a '**patchwork prototyping**' (Floyd et al., 2007; Jones et al., 2007) approach may be useful. It involves the combination and modification of web services, mashups and existing code, functionality and real data from a variety of sources to rapidly iterate high fidelity prototypes through which design spaces and developing requirements are collaboratively explored. Various evolving spatial technologies exist to support this activity. Our experiences indicate that 'real data' are essential in developing and evaluating visualization applications in context and we use a number of flexible and open technologies to produce 'data prototypes' as we explore interactive designs.

7. Geovisualization: Solutions are Task/Data Dependent - What are the Possibilities?

We know that cartographic design for geovisualization needs to be informed by tasks and relate to data. Various typologies exist that may help and others would be welcomed. Andrienko & Andrienko (2006) propose a useful task typology for spatio-temporal data that differentiates between tasks with different levels of complexity and different geographies. Dodge et al. (2008) are developing a systematic taxonomy of movement patterns and encourage the community to participate. This is not a comprehensive list––other and ongoing efforts may help inform geovisualization design.

Transforming the masses of data that are now available into intelligible views through which the subtlety, complexity and structure of spatio-temporal information can be explored in the manner that Fisher described is essential if we are to develop geographic knowledge and support spatial thinking. These 'musings' describe current trends and efforts that may help us develop, augment and explore design spaces for geovisualization as we try to visualize effectively and understand how this is achieved. They show the close relationships between geovisualization and Design, identify some trends that may be relevant to GIS, demonstrate some progress and highlight some of the difficulties that are to be faced.

Combining knowledge from Cartography, GIScience, Computer Science and Design may enable us to support and advance spatial thinking through 'soft,' interactive, aesthetically pleasing, informed maps and graphics that are effectively consumed and adequately designed for user, data and task specific geovisualization.

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