Applying a creative cognition approach to exploratory cartography tool development

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Abstract

Design of visual representation in geographical sciences is in most cases done within the confines of conventions or accepted practices that ensure that the visual designs adhere to, and remain within the realms of the *usual* and *the expected*. This is evident in conventional practices in cartography where map design is overwhelmingly constrained by the need for functional maps that target specific predefined user needs by presenting geospatial facts or engaging users in goal-oriented validation of hypotheses. But when a user's map use objective is to engage in an undirected search for geospatial structures and trends as is the case when seeking to develop probing questions and hypothesis about data, then a different design approach is needed. Today, most emergent visual techniques in exploratory cartographic environments focus on providing an enabling visual environment that can generate, manipulate and interact with geospatial structures embedded within the raw data. Whereas these techniques have elaborate interactive and dynamic data manipulation capabilities derived from presumed conceptual and perceptual user goals, they lack an explicit account of their use and effect in knowledge discovery. Besides, since they have goals that are already anticipated, they in essence are determined and therefore cease to function as exploratory techniques. In this paper we use an approach that outlines the underlying creative cognitive processes and structures that give rise to knowledge discovery and insight. It is derived from previous concepts in experimental methods of cognitive science and, is here adopted to answer questions relating to how emergent geospatial features are detected, synthesized and manipulated for the purpose of discovering new structures, relations and meaning therein. The approach is based on the demise that the possibility of creative discovery in geospatial data exploration is greater if the emergent and unprecedented visual structures are uncommon. We are of the opinion that knowledge of the creative cognition structure is a prerequisite for effective design and evaluation of exploratory visualization tools as will be illustrated by a prototype in cartographic animation.

Keywords : exploratory cartography, creative, cognition, animation,

Introduction

The cartographer's role in the design and production of maps is changing. Previously, and even today, maps continue to function as a means of transferring geospatial information. Cartographers achieve this using stipulated methods and techniques - a type of grammar that allows for the effective design, production and use of maps (Robinson et al, 1995; Kraak and Ormeling, 1996; Dent, 1999; Keates, 1996). But now, the cartographer's new role is seen by the emergent paradigm shift, from a supply to a demand-driven cartography (Kraak, 1998). The trend is further exemplified by what Morrison (1997) calls "democratization of cartography", where the map users are now playing the role of the cartographer, thereby deciding what the contents of the map should be.

Map use within the exploratory realm is characterized by geo-scientists zeal to creatively analyzing raw gesoaptial data in any combination and at any scale using highly interactive tools (MacEachren and Kraak, 1997; MacEachren, 1994). To do this, present exploratory approach relies on the adverse expertise knowledge and the tools that allow the image on display and its data sets to be changed or manipulated interactively. The interactive tools are normally embedded with pre-determined conceptually and, or perceptually motivated exploratory functions. The problem with this approach is that it is a goal-oriented search for structures and patterns in the data and as such only helps to examine existing hypothesis about the data. Here, the specific questions about the data are known *a-priori* and as such the tasks involved reduces to that of indexing and data retrieval (Gehagen, 1998). It therefore falls short of being a visual exploratory tool where users set out on an undirected search of the unknown hidden information in data to come up with hypothesis about the data.

In this paper we pursue the notion that a users' mental representations and cognitive strategies have a profound influence when defining effective cartographic visualization technique. Thus rather than base visual exploratory tool design on data characteristics, and the anticipated tasks that a users are prone to undertake, i.e. their manipulative capability, exploratory visualization tool design should be enacted from the gained understanding in the cognitive processes and structures that lead to knowledge discovery. It is these structures and processes that we intend to use in laying down a framework for exploratory cartographic visualization tool design as will be demonstrated using temporal cartographic animations.

Significance of cognition to cartography

The role that visual images play in facilitating everyday thinking is evident in studies undertaken by Finke (1989); Finke and Shepard (1986); Cooper (1990); Pinker (1984); Shepard (1978); Peterson (1987); Larkin and Simon (1987); MacEachren and Ganter (1990); MacEachren et al, (1992, Beveridge and Parkins,, 1987). The roles encompass those of geospatial information referencing, creative thinking to those attributed to steering scientific discoveries. Their ability to facilitate image transformations by making abstract images explicit has drawn interest in scientific discovery researches (MacEachren, 1985). Contemporary theories of image formation addressed concepts on how features are retrieved from long-term memory and assembled in a mental image to represent familiar objects and forms. A complimentary approach and that which seek to facilitate and highlight emergent features from mental imagery, looks at how features are combined in imagery for the purpose of discovering new patterns, relations, and interpretations (Finke et al, 1992).

Cartographic cognition is also important when one considers the multiple graphic elements that a map-reader interacts with. Understanding the mental processes of these interactions is essential in order to get the most out of the map reading process (Talasli,1990; MacEachren, 1992 and Nelson, 1996). Maps also, facilitate the acquisition of knowledge and communication between users with common interest. These needs have been a primary motivation for cartographer's involvement in studying cognitive processes in mapping. This is so, duly because to design effective maps, cartographers need to understand both the perceptual limitations of the map reader and the mental processes used to interpret and analyze the information on the map. This is even more needed as we face an increasing proliferation of interactive, dynamic and multimedia map products. Researchers here, should address design issues of innovative cartographic tools with the sole objective of guiding and evaluating the design of effective visualization tools (Keller and Wood, 1996).

Comparatively, and with regard to researches in cartographic cognition, there has been a considerable contribution made within the presentational paradigm of map use than on exploration. In the exploration paradigm, map design is complicated by the non-availability of user information (their needs, wishes or intentions) to the cartographer. In fact the challenge to the cartographers is the quest for knowledge on how geoscientists formulate their exploratory objectives, an aspect that needs input from psychology - perception, human vision mechanism and cognition.

Creative cognition and exploratory cartography

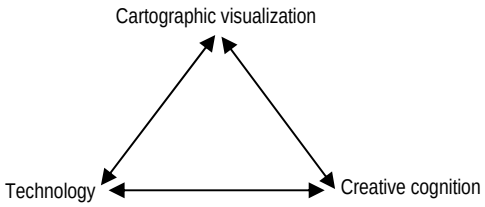
Previous researches in fields of creativity have concentrated on cognitive processes in problem solving, and defining creativity in terms of products (Buttimer, 1983). In cartography, the design and production of a map falls far from creative practices in art, since map production is constrained by the needs and requirements of the organization and clients. Thus most production is undertaken by following laid out conventions or accepted practice. The product is thus confined to within the realm of the expected and the usual. (Keates, 1996).

So what role can creativity play in enhancing cartographic visualization tool development for exploratory environments? There are those who reiterate that creativity *per se* is a purely human endeavour and has no place for technology. But as Shneiderman (1999) puts it,

"….technology has always been part of the creative process…. Supportive technologies can become the potters wheel and mandolin of creativity - opening new media of expression and enabling compelling performances".

The incorporation of creative practices within information technology domains will have profound effects on every institution. This, in cartography will no doubt be paralleled with the already occurring paradigm shift and emphasis on map use changes to meeting private users needs within the exploratory precincts of cartography. In cartographic visualization, just like with other adjacent domains in database exploration, visual data mining, knowledge discovery in databases (KDD), the core objective is the pursuit to understand, develop hypothesis, or make discoveries into an enormous amount of raw geospatial data that comes our way in day to day tasks. Traditional monolithic geospatial analysis approaches don't deliver as they should, and thus we see efforts to integrate core domains as in (MacEachren, et al, 1999 and Gahegan et al, 2001).

To make the best of such complementing approaches to enacting new knowledge, the ability to visualize and imagine must consist of skills to generate images, discover structures and relations in the images, transform the structures, and predict how the structures respond to internal dynamics or external forces. In essence this culminates to an integration of three key disciplines as highlighted in figure 1.



Notes:

- Creative cognition - human capability of generating and evaluating new ideas
- Cartographic visualization - the map use realm that emphasizes exploration of data to generate new hypothesis, knowledge discovery and insight.
- Technology - digital technology for enabling and encouraging creativity.

Figure 1. The merger of the three distinct fields as a means to otpimizing the design, development and use of cartographic tools for geoscientists

Cognitive models

One example of creative cognitive models and that which we use as a basis for our tool definition is the geneplore model. The model serves as a framework of tracing cognitive process and also brings into consideration the diverse aspects of creative performance in terms of explicit cognitive processes and mechanisms. The model highlights three main components of the model: the generative, exploration and interpretation, and the constraints phases. In the generative phase, mental representations having distinct emergent properties are constructed and exploited for creative purposes in the exploratory phase. During exploration, the creative cognition can be varied iteratively depending on the task at hand and its requirements by going back to generative phase. Product constraints can also be imposed on the two phases.

The model's relevance to exploratory cartography tool design is seen by the way that it distinguishes between the cognitive processes (generative and explorative) from the structures they act on (the geospatial features). Also the model helps us to identify the key properties of the generated hypothesis or the constructed knowledge. The validity or quality of these hypothesis or knowledge can further be

evaluated based on how sensible, practical or insightful they are to the specific domain under which the exploration is undertaken.

From a Geographical Visualization (GVis) perspective, MacEachren's (1995) extended feature identification model for map based visualization integrates knowledge about human-perception and cognition that contribute to interpretation of visual information displays. Feature identification and comparison here are forms of a generative process, while feature interpretation emulates the exploratory processes especially on the inferential process of the reasoning why stage. Brewer, (1999) and Gahegan et al, (2001) attribute these inferential processes to abduction. Among the inferential processes abduction is the only one that starts a new idea or scientific explanation. What appears common to both models is the iterative nature between the noticed images (internal or external) and matching them to what is already known (MacEachren, 1995; Judson, 1987; Perkins, 1988).

Incorporating creative cognition in exploratory cartographic tool design gives cartographers an insight and understanding into the underlying mechanisms and phases involved when geoscientists undertake geospatial tasks that are characterized by the key terms; knowledge discovery and hypothesis generation. It is a creative process in that, if equipped with knowledge about how discoveries are made or hypothesis generated, and we incorporate these knowledge in our designs and exploration strategies then one is opt discover new aspects of a phenomena by applying their domain knowledge, experiences or ideas in novel ways.

Identifying exploratory tools : a cartographic animation example

In a broad sense, we can group exploratory cartographic visualization tools according to the two main processes highlighted in the geneplore model; the generative and explorative tools. Generative tools enable one to make observations and descriptions of the data. Visual tools that employ low levels of interactivity could suffice, as all one needs to make initial observations and identify interesting features that will ignite the whole exploratory process. Tools that can find use at this stage of exploration will most likely include those identified by Kraak (1998). Also the tools at this level enable lower inferential processes involving bottom-up encoding mechanisms as with deductive and inductive inferences.

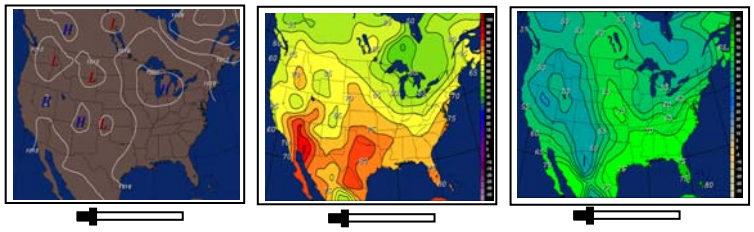
Within the context of exploration using cartographic animation, generative animation tools then, are those that help a user make and describe data or geospatial phenomena during run-time. Basic interactive tools - the media player controls have previously played this role. Tools to allow one observe the data sets under varying geospatial scales or temporal resolutions, categories similarly find a role at this stage. Tools that support lower level inferential processes are dominant at this stage.

At the explorative stage, we need tools to describe the observed data or phenomena. This may entail attribute linking, where the spatio-temporal characteristics and temporal relations between intervals come into play (Claramunt and Theriault, 1995; Allen, 1981). The interrelationships between geospatial data's components can be described using tools that can;

- **Identify** and, or **Locate** *states at a time,* $t_{1,}$
- **Identify** and, or **Locate** *changes between intervals* t_1*, and* $t_{2,}$
- **Identify** and, or **Locate** *events before, after,*
- **Compare (or Associate)** *states and at a time,* $t_{1,}$ **,** *or changes between times,* t_1*, and* $t_{2,}$

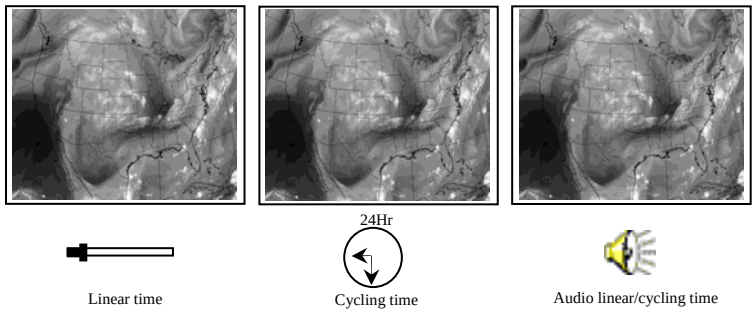
Thus the tools have traditionally been incorporated using legends to identify thematic attributes and transparently overlaid maps for locating places. Lastly, we need tools that can enhance the inferential processes at the interpretation level. Abduction is one key inference logic that plays a role in bringing out new knowledge.
An example of a generative processes using **collocation** is the ability to locate specific animation frames from a set of many based on some user specified temporal or geospatial characteristics. The technique has

previously been used in film and video editing domains. In presentational animation types, sequences of animation frames are pre-selected and played following a predefined linear loop. *Figure 2* illustrates three main facets of collocation in cartographic animations: thematic, temporal and geospatial collocations. **Thematic collocation** *(figure 2a and b)* maintains the theme of the display despite presenting alternating views of different map types without interrupting the message of the display. **Temporal collocation** in this context is the ability for cartographic animations to be viewed under various temporal structures (linear, cycle) or various legend options (audio, graphical or numerical) as illustrated in *figure 2c*. Lastly, **geospatial collocation** is the ability to move between different geospatial scales as in zoom in/out *(figure 2d)* while maintaining the temporal and thematic flow-lines.

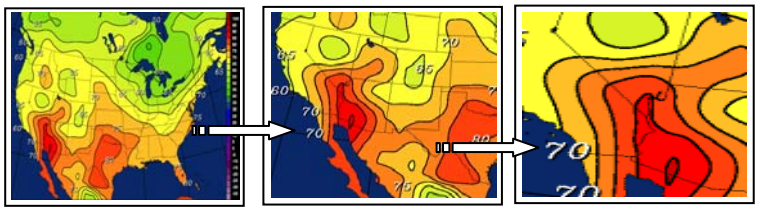


(a) Ability to synchronize themes during animation run-time

(b) Ability to link dynamically multiple maps while maintaining the theme



(c) Ability to synchronize various forms of time structure and legend types at both content and interface



(d) Ability to vary level of detail through zooming in/out

Figure 2. Illustrating some aspects of collocation in animations

In exploratory environments, where enormous amount of animation frames are involved, the need is for animation functionality developers to give users tools that will enable them choose frames from amongst

stored images and define the specific paths that should run by. Alternatively images can be retrieved directly from the database computationally by having the user define the animation path and the system computes and fills in the appropriate images.

More flexible non-linear descriptions of animation frames confines animation not just to one path of view, but also loops and branches. The ability to change what path an animation takes during run-time allows great scope for interactivity. By this an animator just defines a lot of interpolating splines, and at run-time the system determines which one is used. However, this can be very time-consuming, since to make the animation feel very responsive the animator will need to define an awful lot of different segments of animation. What we need are new motion synthesis tools that are responsive in that they allow an animator to describe a range of possible movements concisely. This requires the development of new motion synthesis tools that allow the animation to respond to the user.

Conclusions

Our objective in this paper was to highlight an approach to defining exploratory tools that can be applied in exploratory environments. The environment entails working with raw data having no prior hypothesis at hand. The challenge was then to trace underlying cognitive structures and processes that lead to users formulating a new hypothesis. From the foregoing, the geneplore model is a representative of a typical exploratory working model, and tailors well not only with scientific methods of discovery, but also the geospatial feature identification, comparison and interpretations model in cartographic visualization.

A key to taming the proliferating tools coming about as a result of technological advancements is to formulate a general criterion for visualizations tools, which have a direct contribution to the uses that the visualization is subjected to. The generative and exploratory tools we suggest can be subjected to experimental tests and their contributions to new knowledge formulation found. This is our next challenge; to evaluate the effectiveness of the tools in a scientifically controlled set-up. It is our hope that with this general delineation of exploratory tools, cartographers will find a taxonomy that places the dynamic and interactive aspects of these tools at check in relation to their performances in knowledge construction.

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