CO-269

AUTOMATIC EVALUATION AND IMPROVEMENT OF MAP READABILITY

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1. OBJECTIVES AND CONTEXT

1.1 Context

Users need maps which fit their specific work context. This context may be explicitly defined by users themselves or deducted from the description of their needs: geographical extent, complexity of the treated themes, technical constraints, esthetic preferences, user's physiologic constraints, etc.

Designing these on-demand maps is a complex process for several reasons. Data relevant to the message supposed to be issued by the map have to be selected. They are taken from different sources, thus the symbolization of the data is neither constant nor consistent. However they must be symbolized on the same map because the map message is based on their concomitant visualization, for example: risk map, vulnerability map.

Data are grouped together to make layers and concomitant visualization leads to reading difficulties. The map is less readable because it is densely covered with information. It is difficult to choose which rules to follow for representing data; moreover, it is difficult to know precisely how those rules should be applied [Harrie et al., 2009]. Consequently, the message which is supposed to be conveyed by the map is not clearly communicated because graphic semiotics rules are not respected.

In this context, one important issue is to define a semiautomatic tool that will improve the graphic properties of maps, with a particular focus on readability.

1.2. Problem

The separation of data and their representation, when the user is free to select data and to build his/her own map, can leads to errors. In particular, semiotic errors (low contrast between signs that are next to one another; signs partially hidden by other opaque signs; the use of different level of detail for each data layer, etc) and errors about conventional use of colors (water not represented in blue, vegetation in green, etc) are brought out [Christophe, 2009].

These errors are due to lack of cartographical knowledge which optimizes the symbolization of data on a map. Several studies highlight the problem of readability and, thus, of the effectiveness of the map when not properly designed (Monmonnier 1991, Krygier & Wood 2005). In the context of creating customized maps, automatic methods have to be provided to users in order to increase this readability of maps.

For example, current tools, like Geoportail or GoogleMaps, allow users to make a customized map, but they do not provide cartographic knowledge for analyzing map readability or for applying conventional and semiotic rules. Likewise, they do not offer tools to optimize data visualization on these maps.

Thus, the stacking of layers of data (geospatial data set represented on a single graph plane) on the same map creates difficulties for reading it, among those difficulties:

- The map is less readable when it provides more information;
- The message supposed to be conveyed by the map is not clear because graphic semiotics rules are not respected;
- Difficulty in determining which rules should be applied and how to apply them.

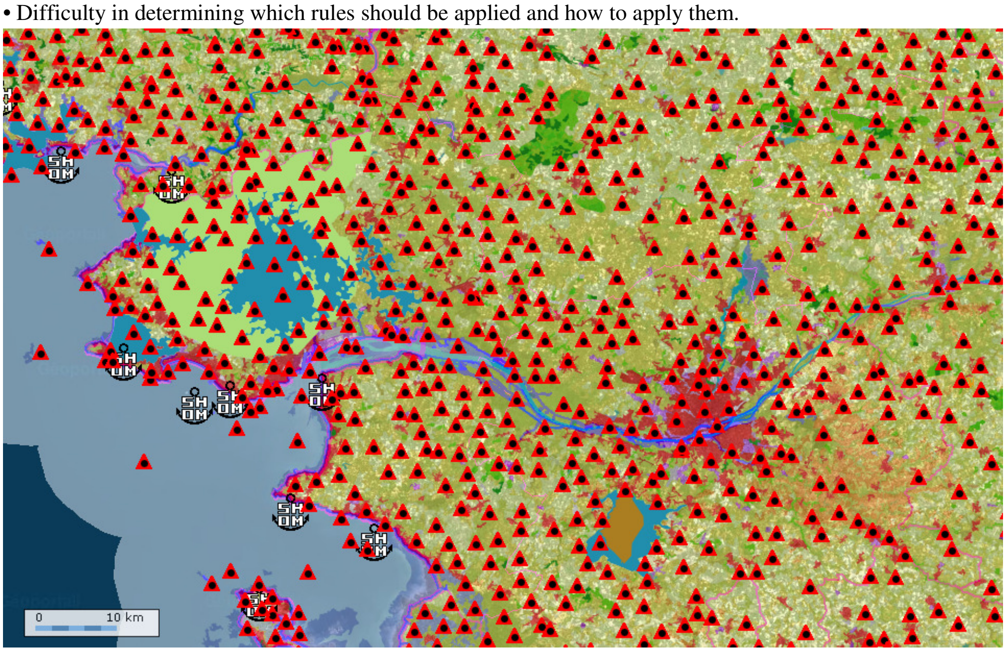

Figure 1 : Map showing the region of Loire Atlantique, displaying many legends what makes it unreadable . (June 2010).

Several studies ([Fabrikant, 2005], [MacEachren, 1995]) are concerned with the proposition of new visual variables, others ([Robinson, 2009]) propose new methods for visual highlighting (using color, transparency, etc …) that can be used in geovisualization. Our research focuses on the automatic evaluation of the visibility of cartographic objects, and on automating the improvements that can be made to the visual rendering of maps.

1.3. Objective

In this paper we present a process for improving visual rendering based on an index system described below. There are three steps to this process: indices calculation, readability evaluation and intervention on the map.

The first step concerns the calculation of indices. An index, in this context, can be a numerical value or a matrix that represents some aspect of the map. The set of indices provides a practical scale for measuring the visual quality of the map according to specific criteria.

The objective of the second step of the improvement process is to determine which characteristics of the map need to be changed to achieve a map of higher visual quality.

The third step performs the modifications that have been previously determined. With each modification of the map, the relevant index value becomes obsolete and therefore must be recalculated.

These three steps will be repeated until getting index values are achieved.

2. APPROACH AND METHODS

2.1. Map creation

The process of improving the map's visual quality is included in a tool that allows users to build a personalized map suited to their needs.

In the most modern mapping tools available, users can create a customized map for themselves by overlapping different layers of symbols. The data can be provided by the tool itself, and data can also be imported by the user. Thus, data may come from heterogeneous sources, which can cause various problems.

In this article for the sake of simplicity we assume that the data handled by the tool is consistent in terms of level of details and generalization.

2.2. Evaluation of the map readability

Readability of a map depends on the visibility of cartographic objects represented on the map; therefore, improving readability requires the improvement of object representation.

This visibility depends on several factors, including compliance with conventional semiotic rules, concordance of an object's size and border thickness, visibility of overlapping cartographic objects and the color contrast (hue and value) between these objects.

To improve the readability of the map, we must first be able to evaluate that readability. For this purpose, a set of indices is defined.

An index is a value that represents several aspects of the map. Each index is tied to a semiotic rule and reflects a particular situation. This situation can be either global or local.

The first one concerns a general feature of the map, such as the color level of the map. The second one relates to a specific feature, such as the color contrast between two objects, or thickness of an object's border.

A change in the situation, through a modification of the symbolization, will alter the value of the index.

3. INDEX SYSTEM

For now, four indexes have been defined:

3.1. Index of recovery

The liberty given to the user to manipulate as many layers of data as he/she wishes can cause readability problems, depending on the density of information handled, particularly problems with cartographical objects being totally or partially obscured by other objects.

This index characterizes the appearance of overlapping objects on the map and helps to optimize the visibility of these objects.

The goal in using this index is to provide the maximum visible area for objects on all layers simultaneously.

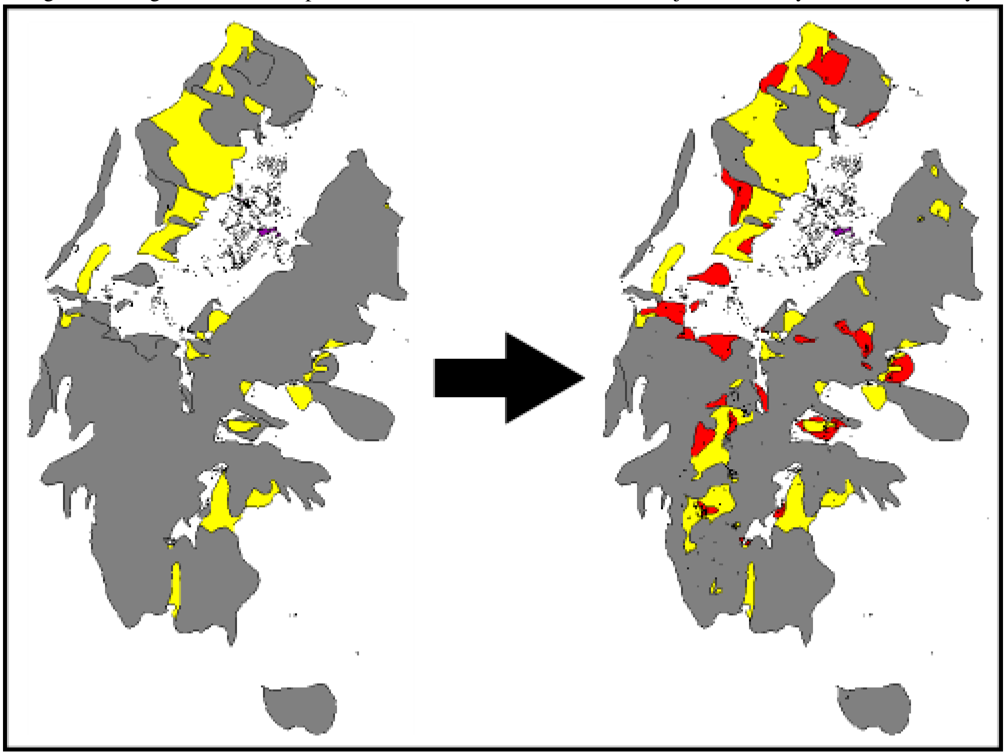

Figure 2: A map with data layers poorly ordered, and the same map after the reorganization of its data layers.

This index includes two variants, a local index and a global index. The local index corresponds to the visibility rate of a particular data layer, while the global index characterizes the visibility rate of all objects on the map.

The algorithm for calculating the index of local recovery is as follow:

• Identifying data layers overlapping the layer in question;

• Merging all these layers;

• Making the intersection between the merged layer and the reference layer

The value of the index is the ratio between the visible surface and the total surface area of the layer.

$$index = \frac{\sum_{i=0}^{n}(STi - SIi)}{\sum_{i=0}^{n} STi}$$

STi : Total surface area of the object number i

SIi : Surface area of the intersection of the object number i and the layers overlapping it

Optimizing this value then means approaching 100%; this is done by minimizing the surface area of the intersection.

The global recovery index is the average of all local recovery indices of the map. It gives the user an overall idea of how much objects are overlapping the map.

3.2. Index of color contrast

The color (hue and value) is widely used in cartography among the variables of visual semiotics graphic [Bertin 1967]. It plays a particular and predominant role since it facilitates the reading and organizing of data. Indeed, the legend is divided into themes, and themes are divided into legend lines. Grouping into themes highlights relations between objects. Use of visual variables hue and value can express the relationship between spatial objects (association relationship, order and differentiation). However, the lack of neighbors objects contrast can cause damage at the perception of these colors by the map reader; some colors may be invisible, distorted, or confused with those neighbors. This leads to the loss of map information.

To reduce these problems, an evaluation of the contrast ratio of map objects in order to improve it, can be a solution. Thus, we chose to reduce the space of possible colors to a color wheel. Many works have been conducted on the perception of color and its use in the maps. [Brewer 2003] suggested color palette adapted for expressing relations between spatial objects. [Chesneau, 2006] created a color wheel which relies on visual variables of hue and value and the contrasts between colors and values [Buard & Ruas, 2007]. This color wheel consists of 12 hues; each of them is derived into 7 intensities of clarity. Hues of gray have been added for the addition of gray in the map. Thus, each color can be localized in a polar space (Z: hue, φ: saturation, θ: brightness).

Then, the index calculation is based on color contrasts and clarity contrasts of Johannes Itten [Itten 1967]. Hue becomes maximum when the angle θ becomes 180°. As for clarity, the two colors have a bigger difference of clarity when Z becomes higher, with a maximum deviation of 7 levels.

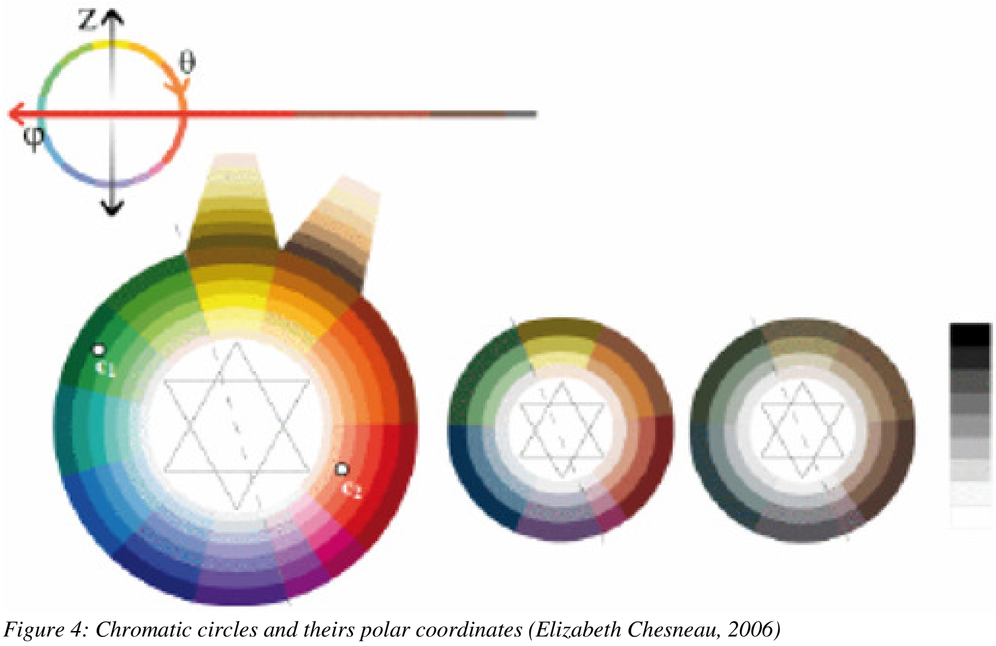

Figure 4: Chromatic circles and theirs polar coordinates (Elizabeth Chesneau, 2006)

The calculation of contrast must take into account the different relationships between objects [Christophe, 2009]. Thus:

• A difference relation should be represented by a strong contrast of hue (high Δθ);

• An association relation between subjects must be represented by similar colors (Δθ low) and contrasted value (ΔZ);

• An order relation between the information ordered (small, medium, large) must be represented by a single color and contrasted values (ΔZ).

3.3. Index of color level

This index can be an effective measure for how much the features of a map “jump out” at users or on the other hand, how “plain” it looks. It can be manipulated to give a map a simpler look, a more special, imaginative aspect, etc. This can be done by determining the solid color on the map, by determining the salience of a particular color, and then react accordingly to the result.

This index does not correspond to a numerical value but to a matrix. This matrix must include all the colors on the map, and contains the following information for each color: amount of map surface in this color, average size of objects with that color, and the surface area of the largest of these objects.

A maximum threshold for each of these parameters must be determined (after testing) in order to judge the color predominance.

Color				
Amount of map surface in this color				
Average size of objects				
Surface area of the largest object				

3.4. Index of border thickness

This index is useful for providing appropriate visibility for small objects. A small object is one with a surface area that falls below a minimum threshold.

When small objects have a relatively thick border it may affect the map user's perception of the object's color. For example, a small white object with a wide black border may be perceived as darker.

This index also includes two variants, a local one and a global one. The local portion of the index is the ratio of the border thickness of a particular object to its surface area. The global one is the average of this ratio for all small objects.

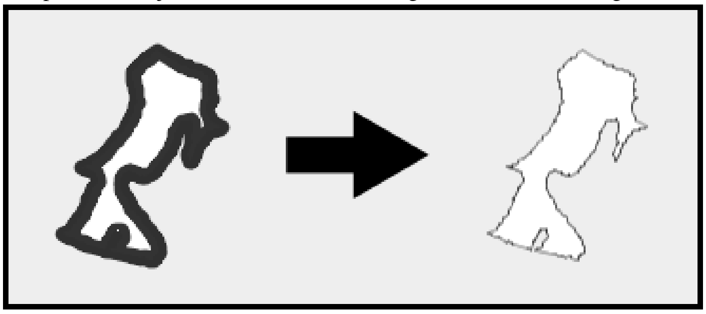

Figure 5: An object with a thick border, and the same object after reducing the thikness of its border.

4. CHANGES MADE TO THE MAP TO IMPROVE ITS READABILITY

After the evaluation of the map visibility and depending on the value of the indexes, changes will need to be made to the map to improve its visibility. This operation will result in the modification of the related index which is recalculated.

4.1. Rearranging the order of the layers

To improve the value of the recovery index, data overlapping must be reorganized using algorithms which are defined here.

The order in which the themes on the map are organized must be determined. This consists in optimizing the visible area of each layer simultaneously. We ignore, in this proposal, the possible semantic issues by putting them all at the same level of priority, and we treat only the zonal data. For this, we treat each theme as if it were on an invisible layer on the map, and all the layers are placed one on top of the other in a stack. The reorganization of the order in which these themes are displayed may be determined using three different algorithms:

- Sort by the largest object in each theme: In this case, the themes are arranged so that the lowest layer contains the object with the largest surface area, the next layer up the next largest object, and so on until reaching the last layer. The largest object on this last layer is smaller than the objects on all of the other layers. This solution quickly reveals its limitations since a layer can contain multiple symbols at once, and the existence of a large symbol does not exclude the possibility of having other small symbols that may be covered by objects on higher layers.
- Sort by total area of each theme: In this algorithm, ordering of layers is determined by the total surface area of its objects. The total area of all symbols of the layer is calculated. The theme with the largest sum is placed on the lowest layer, the theme with the next largest sum is placed directly above and so forth. Therefore, the theme with the smallest sum will be placed on the topmost layer.

As in the previous method, this one also has limitations. For example, we may have two layers, one composed of several small elements and the other composed of a single large element. If the sum of the element's surface areas for the first layer is larger than the surface area for the second, then the second layer will be placed above the first, running the risk of the small elements (in the first layer) being covered by the large element in the second layer.

- Sort by the average area of each layer: For this proposal, the ordering of the layers is done using the average area of the symbols on each layer. Thus, the theme with the largest average surface area of elements will be placed on the lowest layer, and the theme with the smallest average surface area of its elements will be placed on the highest layer.

4.2. Changing the border thickness

If the imbalance is important between the thickness of an object border and its surface, two solutions are possible:

- If the problem affects a small number of objects (not necessary from the same theme), we can modify the borders thicknesses of concerned objects. Indeed, this modification does not alter the global visual rendering of the map, while highlighting more the affected objects.
- On the other hand, if the problem concerns a larger number of objects, we must change the default border thickness for all objects on the map in order to correct the problem without adversely affecting the map as a whole.

4.3. Color modifications

The process of color change is achieved gradually to lead to more pronounced contrasts and better perceived colors. Depending on the distances calculated above, we check if the colors are consistent with the semantic relations between topics (associations, difference or order). If they are, we check if the distances are sufficient to perceive correctly the difference between the two colors. And if the colors are not consistent with the semantic relations, one of them must be changed. The choice of this color is made arbitrarily. Following the changes of colors, a new analysis of contrasting colors will be performed. If this second condition gives better global results for color choices, it will be validated. Otherwise, we return to the previous state and we test the change of a second color. This process is repeated until the color contrasts on the map is satisfactory.

These changes modify the value of both color contrast index and color quantity index. So, we have also to reevaluate this second one in order to verify its value.

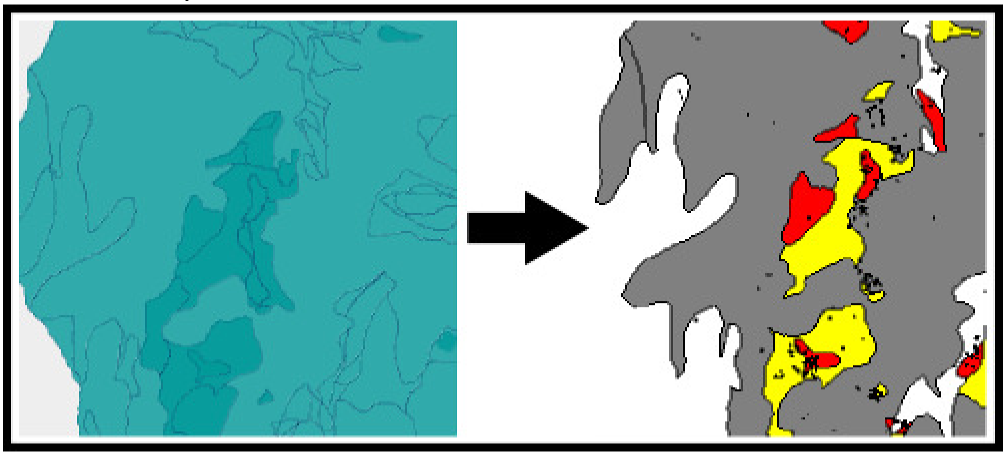

Figure 6: A map with poorly contrasted colors, and the same map after the correction of its colors contrast.

For each color (hue), we get (from the matrix previously calculated) the rate of visible map surface with the same hue. If this surface is greater than 35% of the total area of the map, and if the values of this color are close, we can deduce that this color is predominant. In this case, a solution could be (if possible) the accentuation of difference between the existing values of that color by taking them away from each other on the circle. Then the quantity index of colors is reassessed and the process repeated until we have the distance between the values of colors satisfactory.

This modification also alters the color contrast index which has to be reevaluated.

In all cases, each change of symbolization on the map alters the index value associated with this symbolization. Changing the order of the layers modifies the value of recovery index, quantity of colors and colors contrast. Changing the thickness of the edge modify its index.

Changing colors of objects alters both colors quantity index and colors contrast index.

5. CONCLUSION AND PERSPECTIVES

In the outline of a map building tool for a novice user, we are interested in improving the readability of the map by correcting visibility errors of cartographic objects. To do that, a first step of visibility evaluation is defined, based on an indices system to help evaluate different aspects of visibility on the map. The proposals in this paper is mostly theoretical, the short-term goal would be an implementation and a testing phase in order to validate them. On the indices, the size of objects must be taken into account in the contrast of colors. Indeed, the size of objects can affect the perception of colors and can also affect the perception of the colors of objects neighbors. We expect this purpose, the weighting of the indices (and the values in the matrices) with the sizes of these objects. Another perspective consists in taking in consideration the semantic of themes and objects. Indeed, the map is primarily intended to be read, the semantics is a very important aspect in the process of building the map in order to target the message purporting to be issued by this map. Thus, the visibility of more important objects will be prior than that of the lesser importance objects. Further research in this direction should be made.

6. REFERENCES

Bertin J., 1967, *Sémiologie graphique : les diagrammes, les réseaux*, les cartes, First edition 1967, then 1973, 1988, Paris, Editions of E.H.E.S.S.

Brewer C., 2003, *A Transition in Improving Maps: The ColorBrewer Example*. Cartography and Geographic Information Science. Vol.30, n°2, pp. 159-162.

Chesneau E., 2006, *Modèle d'amélioration automatique des contrastes de couleur en cartographie - Application aux cartes de risques*, PhD Thesis, University of Marne-La-vallée, IGN, France.

Christophe S., 2009, *Aide à la conception de légendes personnalisées et originales : Proposition d'une méthode coopérative pour le choix des couleurs*, PhD Thesis, University of Marne-La-vallée, IGN, France.

Dominguès C., Christophe S. and Jolivet L., 2009, *Connaissances opérationnelles pour la conception automatique de légendes de cartes*. In Actes des 20èmes Journées Francophones d'Ingénierie des Connaissances (IC2009), 25-29 mai, Hammamet (Tunisia), pp. 253-264

Fabrikant S.I., 2005, *Towards an understanding of geovisualization with dynamic displays*. Proceedings, American Association for Artificial Intelligence (AAAI) 2005 Spring Symposium Series: Reasoning with Mental and External Diagrams: Computational Modeling and Spatial Assistance. Stanford University, Stanford, CA, March 21-23, p. 6-11

Harrie L., Mustière S., Stuckenschmidt H., Stigmar H., *Cartographic aspects of geoportals.* Presenting Spatial Information: Granularity, Relevance, and Integration, Workshop at COSIT'09, september 21st, 2009, Aber Wrac'h (France)

Itten J. 1967, *Art de la couleur*. First edition in 1961: Kunst der Farbe, translated in French in 1967, then 2001. Ed. Dessain and Tolra.

MacEachren A., 1995, *How maps work : Representation, Visualization, and Design*. Guilford Publications, New York.

Monmonier M., 1991, *How to lie with maps*, University of Chicago Press.

Krygier, J. & Wood, D. 2005, *Making maps: a visual guide to map design for GIS*, New York: Guilford Press.
Robinson A. C., 2009, *Visual highlighting methods for geovisualization*, 24th International Cartographic Conference (ICC'09), November 15th-21st, Santiago (Chile).