HyperSmooth: A System for Interactive Spatial Analysis Via Potential Maps

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Abstract. This paper presents a new cartographic tool for spatial analysis of social data, using the potential smoothing method [10]. The purpose of this method is to view the spread of a phenomenon (demographic, economical, social, etc.) in a continuous way, at a macroscopic scale, from data sampled on administrative areas. We aim to offer an interactive tool, accessible through the Web, but ensuring the confidentiality of data. The biggest difficulty is induced by the high complexity of the calculus, dealing with a great amount of data. A distributed architecture is proposed: map computation is made on server-side, using particular optimization techniques, whereas map visualization and parameterisation of the analysis are done with a web-based client, the two parts communicating through a Web protocol.

Keywords: multiscalar spatial analysis, potential maps, interactive maps, spatial decision support system.

1 Introduction

Recent advances in the Web domain have led to new research issues in interactive and dynamic cartography (Cartographic Web) [8]. In this context, the interdisciplinary research group *HyperCarte* which gathers researchers in Geography, Statistics and Computer Science works on the design and development of a set of interactive spatial analysis tools for the representation and the analysis of social, economic and environmental phenomena. Cartographic Web technologies represent a possible approach as they grant flexibility and interactivity. Indeed, spatial analysis consists in the exploration of spatial data in order to formulate, compare and validate hypotheses. The strong link between interactivity, exploration and data analysis is described by MacEachren [13] through the "map-use cube" which represents visually the degree of interactivity, the type of target and the degree of data knowledge necessary for the user in the *Exploration, Analysis, Synthesize and Presentation* steps of the spatial decision making process. A map is interactive if it gives access to other data [1], [11]. For instance, through a simple click on a part of an interactive map, a new piece of

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information (another interactive map, a multimedia document, etc.) can be accessed. There is no complex query language to be mastered by the user. Thanks to this, one can touch a wider public, allowing non-computer science aware people, such as policy makers, geographers, statisticians, stake holders, and so on, to create potential maps.

This paper describes *HyperSmooth* a tool based on the Web, which generates dynamically continuous interactive maps using administrative, environmental, or economical data, collected on grids or territorial meshes. HyperSmooth implements a smoothing method, called the *potential transformation method* [10], which provides multiscale cartographic representations, abstracting the real observed data. More specifically, the goal is to visualize and analyze the spatial distribution of socio-economic phenomena at a macroscopic level. So far, no Geographic Information System (GIS) [12] and Exploratory Spatial Analysis tool [6] offer an interactive analyzis of true potential maps. The main issues of this spatial analysis method and of its cartographic representation are its high computing cost, which generally hampers interactivity. To overcome this problem, Hypersmooth distributes the computation on a multiprocessor server, which performs a parallelization of calculation tasks, making possible the visualization of maps for a web interactive client with a secured connection.

The paper is structured as follows. Section 2 presents the research motivations that have led to HyperSmooth. The potential transformation method is described in section 3. Our prototype is presented in section 4, and section 5 shows the results of our approach. Conclusion and future work are detailed in section 6.

2 Research Motivations

2.1 Using Exploratory Spatial Data Analysis Systems

Geographic Information Systems (GIS) allow storing, visualizing and analyzing spatial data [12]. Spatial data can then be analyzed by means of geostatistic and classical analysis tools. Commercial GIS implement several vectorial data analysis tools (i.e. buffer, overlay, etc.). Some interpolation methods to create continuous maps (i.e. Inverse Distance Weighted (IDW), Krigging, Spline Polynomial Trend) have also been implemented. Yet it has been recognized that GIS are not Spatial Decision Support Systems (SDSS) [7]. SDSS helps decision makers to solve spatial decisional problems by providing a simple, interactive and flexible interface, managing aggregated data, handling complex spatial data structures (i.e. spatial hierarchies, field data, networks, etc.), and granting effective response times. Different kinds of SDSS have been developed. For instance, Visual Spatial Data Mining systems [3] integrate spatial data mining and GIS functionalities, Spatial OLAP tools add GIS functionalities to OLAP systems [2], and the Exploratory Spatial Data Analysis tool (ESDA) [6] allow exploring vectorial and field data by means of interactive maps and graphic displays (scatter plots, histograms, parallel coordinates). In these systems, users can interact with the map and trigger spatial analysis operations. Spatial analysis tools for field data implemented in SDSS systems offer many functions such as: summarization (i.e. data is aggregated for each cell of the grid map), reclassification (i.e. data value is transformed using data mining algorithms and/or statistical methods, etc.), change of