A Classification Scheme for Lens Techniques

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Abstract

For the visualization of abstract information with spatial dependencies, the combination of icon representations with maps is widely accepted. However, with an increasing amount of data creating complete, yet not overloaded, visualizations becomes evermore difficult. Effective interaction methods are therefore needed to discover hidden information in these pictures. Lens techniques offer the potential to efficiently combine proven methods from cartography and information visualization. Such techniques are not yet exploited sufficiently, exemplified by how little effort has been made so far in even systematizing lenses used in different fields.

This paper introduces a common classification scheme that integrates known techniques and provides points of departure for new approaches. Derived from this work, a novel lens technique for the explorative analysis of maps is presented. The effectiveness of the proposed lens is demonstrated in an existing system for the visualization of health data.

Keywords

Visualization, Multivariate Data, Spatial-dependent Data, Cartography, Iconic Techniques, Lens Techniques.

1. Introduction

Data sources such as surveys or simulations generate vast amounts of raw data. Information visualization has turned out a wealth of methods for the efficient and comprehensive visualization of complex information spaces as depicted e.g. in [Tuf90]. However, most approaches give little or no regard to any (geo-)spatial dependencies. Applications such as multispectral satellite images and healthcare statistics are examples for geo-referenced, multivariate information.

Cartography is about effectively presenting large geographic data sets with different granularity on thematic maps. Tried and proven concepts for the creation of high-quality maps have lately being augmented with automated methods to create on-screen maps. However, visualizing data on maps is mostly still confined to low-dimensional, unstructured information spaces.

Of course, ways to combine the expertise from both fields has been studied before (e.g. [Sku00, KrOm96]). Despite the sophistication of cartographic and information visualization techniques, it is often impossible to represent all relevant information in one image. The user must be able to interactively browse and explore the representation in order to gain satisfactory insight from the data.

One way to meet this requirement is to seamlessly integrating multiple levels of detail within the same representation, i.e. focus & context concepts with interactive repositioning of focus areas, as examined e.g. by [Kea98].

Viewing focus regions in such focus & context representations as lenses takes this concept one step further. Lenses can be stacked on top of each other to create combined effects (cf. [SFB94]). Thus, lenses are locally confined, chainable operators applied to the visualization pipeline.

Despite their usefulness, only little effort has been made to classify lenses in more detail. By systematizing the major principles of lens functionality, one gains the ability to adapt and combine already existing methods in new and beneficial ways. Therefore this paper will introduce

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a common classification scheme that was the basis for the development of novel lens techniques.

The paper is structured as follows: In section 2, methods from cartography and information visualization that can be used for lens techniques will be presented shortly. Section 3 abstracts the characteristics of lenses and pictures them in a uniform classification scheme. A novel technique will be introduced in Section 4. Section 5 concludes with some results.

2. Basic concepts for lens design

Lens techniques typically realize some kind of optical distortion in a confined region (defined by its position and shape) of an image which allows the user to take a closer look at interesting details. As shown e.g. in [SFB94] there is a wide range of extending functionalities available. With geospatial data in mind, we will have a look on established concepts from Information Visualization and cartography to enhance lens techniques.

Focus & context applies specific transformation and magnification functions (see [LeAp94]) to control the magnification in the focus region as well as the miniaturization in the context region. This concept can be adapted as a lens technique so that the functions do not influence the representation outside of the lens region.[1]

The **overview & detail** concept can be used for lens techniques as well, e.g. by placing a detailed, semi-transparent layer above the overview layer. This differs from focus & context in that no distortions have to be applied.

Information hiding lenses work by filtering out superfluous data and thus emphasizing important information in a confined region. Such lenses can use different layers, selecting only a subset of layers to be shown (e.g. the ’Moving Filter‘ [SFB94]).

Even time-consuming cartographic methods can be used for lens techniques when restricting their application to a confined lens region only.

A **visual hierarchy** (see e.g. [HaGr94]) arises from the variation of visual variables like color, saturation, or sharpness (see [Ber74], [KrOm96]). For example, crisp picture elements are visually more prominent than blurred ones (cf. [KMH01]). Porting this general approach to lenses means that a given visual hierarchy is altered in the lens region, e.g. by moving objects matching certain criteria to the top of the (imposed or given) hierarchy.

Generalization is an important concept in cartography to adapt a highly detailed base map to smaller scales. A ‘generalization lens’ addresses the presentation problem locally by graphic or semantic (concerning the data) simplification, classification, scaling, displacement, aggregation and subset selection of map features (cf. e.g. [HaGr94]).

Cartographic **labeling** uses sophisticated methods to shape objects and optimize their position on a map. However, good quality labeling for a large number of features is very hard to achieve in interactive times. Confining labeling to only a lens region reduces both the number of features as well as the general complexity of the task.

3. Development of a classification scheme for lens techniques on maps

In the following, the aspects contributing to the lens classification scheme are presented.

3.1. Fundamental type of lens

The first point of distinction for lens techniques is how they fundamentally function: either in a purely graphical way, or by operating on a semantic level. Spatial transformations (magnification, distortion), the variation of visual variables and the relocation of map objects are graphic techniques, while an increase or a reduction of information content as in information hiding or in generalization methods are techniques with semantic effects.

3.2. Integration in the visualization pipeline

The second criterion to classify a lens is the stage of the visualization pipeline modified by that lens. The principal possibilities are the realization as an additional filter operation, a modification of the mapping process, or the use of a different renderer for the lens region. The latter variant could be directly integrated into the visualization process, or be employed on the finished raster image (making that lens an independent, detached tool).

Obviously, which pipeline stage is modified is not completely independent from the first criterion, as any semantic change can only be achieved during the filtering and/or mapping stages of the pipeline.

3.3. Lens parameters

The third aspect of classification are the principal lens parameters: its position on the map, its shape and means for its adjustment (influences).

The most common way to position a lens is probably by user interaction (pointing with the mouse), but also data- or context-driven means are possible. Examples are moving the lens in reaction to changes to the data set (a new entry has been added or altered), or the automatic positioning of the lens in response to some user query, e.g. for a maximum

[1] Note that focus & context, and thus lenses, are not confined to magnification effects. Keahey uses the notion of a ‘detail axis’ [Kea98], with the meaning of detail being domain-specific.

value. Likewise, the lens' shape is a parameter that can be changed as required. It can be a simple, fixed geometric form, e.g. a circle. Or it can be a more complex shape that is adjusted according to the current situation. Prime example would be a lens that always encloses complete map areas, and thus would have its shape defined by whichever map area the lens is positioned on.

Furthermore certain events, system requirements, or time may be used to generally parameterize the lens function aside from position and shape and hence should also be taken into account for classification.

3.4. Presentation with lens techniques

Leung & Apperley [LeAp94] distinguish distorted and undistorted views. Following their concept we also want to classify lenses by their distortion effects. For graphical lenses this means whether or not a straightforward optical distortion is applied within the lens area. With semantic lenses, one could distinguish if presented information will be gathered by simple selection (undistorted) or computed by appropriate functions (distorted).

Finally, the actual means by which the lens operates on the data is the last, if most diverse, classification aspect. It can be any applicable information visualization or cartographic methods, e.g. simple graphical magnification, creating visual hierarchies, or semantic generalizations (cf. Section 2). These criteria are universal enough to be useful for lens techniques in general and are therefore integrated into the classification scheme.

There are of course other distinctions possible, e.g. according to the kind of relevant events, the kind of used algorithms or data structures. Such criteria are quite special and go beyond a general systematic so that they were not regarded. Table 1 summarizes the mentioned criteria.

To demonstrate the classification of lens techniques by our scheme we will categorize an established approach: Rase's 'cartographic lens' [Ras97]. It is a *graphic* lens operating at the *rendering stage* of the visualization pipeline by repositioning points in the geometric space. The shape is a circle of *fixed* size, defined by a focal point and a given radius. The focal point can be moved around a map (*user-controlled*). Parameterizing influence comes from *user interaction*. By nature of the employed fisheye projection, the lens realizes a *distorting* (non-uniform) graphical *magnification* effect across its area.

To summarize, our categorization scheme allows the classification, evaluation and comparison of lens techniques. Moreover, on the basis of this scheme special lens types regarding the requirements of a given application can be developed.

<table>
<tr><th>Criterion</th><th colspan="60">Possibilities</th></tr>
<tr><td>Fundamental type</td><td colspan="30">Semantic</td><td colspan="30">Graphic</td></tr>
<tr><td>Integration into the visualization pipeline</td><td colspan="15">Filtering stage</td><td colspan="15">Mapping stage</td><td colspan="15">Rendering stage</td><td colspan="15">None (image post-processing)</td></tr>
<tr><td>Lens parameters</td><td colspan="60"></td></tr>
<tr><td>Shape</td><td colspan="20">Fixed</td><td colspan="20">User-controlled</td><td colspan="20">Data/context-driven</td></tr>
<tr><td>Position</td><td colspan="30">User-controlled</td><td colspan="30">Data/context-driven</td></tr>
<tr><td>Influences</td><td colspan="12">User interaction</td><td colspan="12">Events</td><td colspan="12">System requirements</td><td colspan="12">Time</td><td colspan="12">Other</td></tr>
<tr><td>View type</td><td colspan="30">Distorted</td><td colspan="30">Undistorted</td></tr>
<tr><td>Method/Operator</td><td colspan="60">Various (visual hierarchies, magnification, ….)</td></tr>
</table>

Table 1: Categorization scheme for lens techniques (adapted from [Gri04])

4. A new lens technique for LandVis$_t$

LandVis$_t$ is a system for the visualization of health information. For a German federal state health insurance data (the number of people who reported sick in a period) are displayed. LandVis$_t$ uses icons on an administrative map which is organized in three resolution levels: state, districts and zip-code areas. One of these icons, the maximum icon, encodes in a 'clock hand' at which time most reports occurred. Placed on a map these icons give an impression on the spread of a disease (see [Tom02]).

Unfortunately, at higher map resolution levels the representation becomes cluttered as a growing num-ber of icons has to be placed. The integrated Carto-graphic Lens [Ras97] can declutter the representa-tion locally, however only within limits. Thus, more sophisticated lens techniques are needed. As an example we will now introduce a selected technique from [Gri04] that operates on the filtering stage of the visualization pipeline: the Aggregate-Lens.

Influencing the visualization at the filtering stage allows the most complex adaptations. The general idea of the Aggregate-Lens is to aggregate any given data within the lens region into a compact overview representation. Examples are the calculation of averages and sums or the determination of extreme values, outliers and other characteristic properties. Such a lens dissolves local clutter and allows the user to gain a flexible and quick impression on the main characteristics of a region.

As an example specific to LandVis$_t$, the Aggregate-Lens was implemented in a way that it summarizes the maximum icons within its boundaries. It displays a single modified maximum icon that shows the average peak time over all map areas at which a certain disease reached its maximum spread in the lens region. These map areas are selected upon inclusion of the bounding box centers in a movable selection square and are highlighted accordingly (see Figure 1 left).

As supplemental information to the average peak time, the Aggregate-Lens displays the overall time interval of all peak times as a circle segment around the clock face. Furthermore the standard deviation is encoded in the color of that circle segment using a blue-red color scale (low to high deviation). Last, the most extreme outlier is shown as a yellow clock hand in the according map area (Figure 1 left).

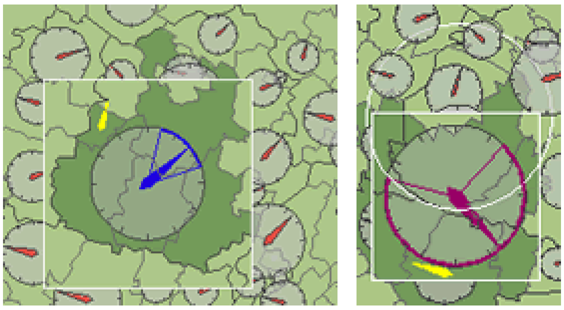

Figure 1: Aggregate-Lens (left); example for its combination with a Cartographic Lens (right)

Classification: The Aggregate-Lens is a *semantic* lens operating on the *filtering stage*. Its position is solely *user-controlled* (with a mouse). While the user can specify the size of the selection rectangle, the form of the lens is determined by geographic conditions, i.e. it is *data-driven*. Parameterizing influence originates from *user interaction*. The presented information is modified by a function, so the Aggregate-Lens is a semantic *distorting* lens. The content of the lens is displayed by means of *modified icon encoding*.

5. Conclusions

An effective visualization requires sophisticated interaction methods. Within the considered context of geo-spatial multivariate data, lens techniques are a suitable choice.

Despite its application capabilities these techniques are rarely systematized in literature. This paper therefore proposed a common classification scheme for arbitrary lens techniques, based on a review of applicable techniques from both information visualization and cartography.

As an example, the Aggregate-Lens was proposed that declutters the representation by displaying statistical moments of a number of data sets. An implementation example specifically for health data using icon encoding was presented.

Another aspect of lens techniques is its possible combination, as shown in Figure 1 (right). Using the proposed classification, expedient combinations can be found, as examined in more detail in [Gri04].

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