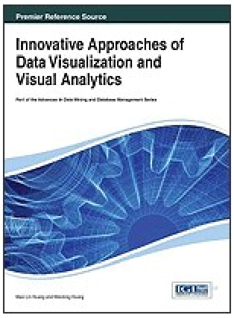


# Innovative Approaches of Data Visualization and Visual Analytics

by Mao Lin Huang and Weidong Huang (eds)

# Chapter 13: From Data-Centered to Activity-Centered Geospatial Visualizations

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## ABSTRACT

As geospatial visualizations grow in popularity, their role in human activities is also evolving. While maps have been used to support higher-level cognitive activities such as decision-making, sense making, and knowledge discovery, traditionally their use in such activities has been partial. Nowadays they are being used at various stages of such activities. This trend is simultaneously being accompanied with another shift: a movement from the design and use of data-centered geospatial visualizations to activity-centered visualizations. Data-centered visualizations are primarily focused on representation of data from data layers; activity-centered visualizations, not only represent the data layers, but also focus on users' needs and real-world activities—such as storytelling and comparing data layers with other information. Examples of this shift are being seen in some mashup techniques that deviate from standard data-driven visualization designs. Beyond the discussion of the needed shift, this chapter presents ideas for designing human-activity-centered geospatial visualizations.

## INTRODUCTION

Geospatial visualizations are digital geographic and/or spatial maps to which users or designers can link their data. Due to the widespread availability of map application programming interfaces (e.g., Google Maps, Google Earth, Bing Maps, OpenStreetMap, and others), geospatial visualizations have become common tools in many human activities. Climatologists, biologists, linguists, literary researchers, business analysts, real-estate agents, journalists, historians, librarians, archivists, geologists, social scientists, educators, archaeologists, health and medical professionals, and others have adopted various types of maps for data visualization (Shandler, 2012; Bailey et al., 2012; Boggs et al., 2012; Nunn & Bentley, 2012; Xie & Pearson, 2010; Skiba, 2007). Broadly, designers create geospatial visualizations using three approaches. First approach is taken by those who design simple Web 2.0 tools such as Fusion Tables, Flickr, Historypin, or SIMILE Widgets. Second approach is taken by those who, having more advanced programming skills, use data-centered models, developed by geovisualization and information visualization researchers, to design time maps, coordinated displays, and dynamic query interfaces. Third approach is taken by those who design activity-centered geospatial visualizations—examples of which include Historypin, an online, user-created archive of historical photos and personal recollections (Historypin, n.d.) and Marine Map decision support tool (South Coast Regional Stakeholder Group, n.d.). These visualizations are geared towards supporting user tasks and activities. The first two approaches result in more-or-less data-centered visualizations, and the third approach is intended to produce human-activity-centered visualizations. The distinction between data-centered and activity-centered visualizations lies in the focus of their designs. Whereas data-centered visualizations are primarily focused on and concerned with representing empirically or mathematically derived data values, activity-centered visualizations focus on representations and interactions that support user's goals, needs, and real-world tasks and activities. As there is scarcity of research with regard to how to design activity-centered geospatial visualizations, in this chapter, we discuss how geospatial visualizations can be made more activity-centered and suggest some ideas and techniques.

In this chapter, human activities refer to "clusters of actions and decisions that are done for a purpose" (Saffer, 2010,). Tracing one's genealogy, deciding about a real-estate purchase, making sense of medical records, or finding the cause of a disease outbreak are examples of human activities. Activities may range from simple ones, such as finding a specific location or retrieving driving directions, to complex ones, such as determining the cause and effect in natural phenomena or drawing conclusions about the data coming from multiple sensors or map layers. A single activity may involve many tasks and subtasks (Sedig & Parsons, 2013). For example, determining the causes of some social activities (e.g., riots or strikes) may involve a number of visual comparisons of several map layers with the locations of riots and strikes, reading newspaper articles and social media messages about them, and determining proximity to some important landmarks. As such, it can be seen that there are differences between the complexity of higher-level activities that people perform and the less complex lower-level computational and preparatory tasks that help them complete these activities.

Understanding user tasks and activities is essential for the effective design of activity-centered visualizations. Geospatial visualizations should be designed such that they support users to tell spatio-temporal stories, to make comparisons between different data, to draw extrapolations from data, to generate hypotheses, to observe trends in data, and to perform other tasks that collectively give rise to more complex activities at hand. Ideally, these visualizations should create conditions whereby users would not assume that maps can only provide limited "snapshots of reality" (Cartwright, 2009), nor that they are not able to support high-level sense-making activities (Elias et al., 2008). Sedig and Parsons (2013) suggest that one of the main roles that computational tools, such as these interactive visualizations, can play is epistemic—that is, they should support, extend, partner, and supplement the cognitive functionings and activities of their users, activities, such as decision-making, learning, problem solving, and analytical reasoning. With this in mind, geospatial visualizations can be thought of as tools that can and should support epistemic activities of users.

Identifying tasks in human activities is, however, challenging. Firstly, higher-level cognitive activities are neither clearly defined, nor easily understood. Compared to mundane tasks (such as operating an airline booking system, using an ATM, or checking out a library book), higher-level cognitive activities are complex, difficult to observe, interwoven with various other tasks and subtasks, and situated within intricate social contexts and networks (Casner, 1991; Rogers & Ellis, 1994; Sedig & Parsons, 2013). Secondly, few real-world human activities start with the use of maps. For example, genealogical researchers start looking for information in books, gazetteers, articles, pamphlets, and other sources; they consult maps only at the end of their search (USGS, 2002). Geospatial visualizations, however, can change the flow of users' activities.

For example, while 20 years ago no one could even think about searching for business-related information on digital maps, today geospatial search engines are so ubiquitous that many find it difficult to locate business information without them.

The remainder of this chapter focuses on the gap between data-centered and activity-centered designs. We will explore how traditional data-centered visualization designs fail to facilitate higher-level human activities, and how they can be rendered more suitable through activity-centered design. The next section provides background information about the roles and characteristics of different components of map application programming interfaces in geospatial visualizations. The overview section presents an overview of popular geospatial visualizations that have had a significant impact on the design of other visualizations. The section about tasks, activities, and interactions introduces theoretical underpinnings of tasks and activities. An example of real-world human activity—specifically real-estate decision-making— is given in the next section. This section highlights why data-centered visualizations fail to support them. Using the real-estate example, the section that follows discusses some design considerations that can make data-centered visualizations more suited to human tasks and activities. Finally, the concluding section provides a summary of the ideas discussed in the chapter.

## COMPONENTS OF MAP APPLICATION PROGRAMMING INTERFACES

Before discussing design principles, we discuss the different layers of geospatial visualizations, where layers refer to different strata of representations and geospatial visualizations are created by combining these layers.

### Data Layer

The data layer (in GIS parlance also known as a vector layer) consists of points, lines, and polygons, typically used to characterize distinct entities such as houses, roads, or districts (United Nations, 2000). This layer can have a composite structure, as it can include gazetteers (i.e., spatial data) as well as metadata (i.e., properties or attributes of data). The former is a dictionary of geographic locations containing information about location names, types, and coordinates. The latter contains information about the source, temporal coverage, and other properties of the metadata, though not necessarily the information entities themselves. Gazetteers and metadata can have cross-references to each other. For example, metadata can be linked to locations described in a gazetteer.

### Base Map Layer

The base map layer contains geographical reference information upon which the data layer may be plotted for purposes of comparison or geographical correlation (Robinson et al., 1995). Preferences for base maps differ depending on the user's background and purpose. For example, epidemiologists use demographic maps for the presentation of aerial data, relating disease rates to spatial areas in the hope of finding "clues of aetiological significance" (Forster, 1966). Demographic maps provide epidemiologists with information about the size of the population at risk, indicate rates and locations of diseases in local populations, and allow weighting of local differences (Forster, ibid.).

Map application programming interfaces most commonly provide road, satellite, or aerial maps as a base layer; however, these are not necessarily the most suitable representations for supporting users' tasks. As Hill (2006) and Elias et al. (2005) have suggested, base map layers should display boundaries or landmarks that are familiar to users and be tailored to their tasks and activities—that is, they should be activity-centered and fit the user and the task, and not provide pre-packaged data-centered maps.

### Google Maps Layers

Google Maps has additional thematic data layers, including Wikipedia, Demographics, YouTube, Panoramio, Weather, and Bicycling layers, which enhance base maps and enrich users' understanding of location. These are developed by third-party programmers and are available as open-source data. The Panoramio and YouTube layers augment users' understanding of places through imagery and video. The Wikipedia layer helps users to explore unknown locations with crowd-sourced descriptions by integrating location information from the web. The Demographics layer "contain[s] United States census information … from recent years as well as 5-year projections of many data fields" (Google Developers, 2012a). It can be used for showing population size, age, race, household income, marital status, household size, and other demographics. The Weather and the Bicycling layers facilitate understanding of local weather and bicycle trails.

### Other Layers

Besides base map layers, many mashups merge multiple KML[1] or GeoRSS[2] files and present them as a single map layer (Elias et al., 2005), where a mashup is the combination of several data sources in one interface. While individual files may have small regional coverage, synthesized files can create layers that cover the whole world. For example, GeoRSS news files, amassed from various websites and RSS feeds, can be combined into one large news map.

Layers differ in the structure and characteristics of their interactions. Data layers, for example, are the most malleable. They can be decomposed into individual metadata properties which can be grouped, regrouped, filtered, or transformed in many different ways. Data properties can be used for developing symbols and other representations, or they can be grouped and used for creating more generalized derived representations (e.g., heat maps). Base layers and additional layers are not as flexible as data layers. In base map layers, designers can change certain aesthetic properties, such as hue, lightness, saturation, gamma, visibility, and color; modify content by adding or removing feature types, such as administrative, landscape, road, transit, and water features; and add or remove labels for all these features. However, base layers do not contain any metadata about individual properties of feature types, as these properties can be available via a different API; that is, markers in Wikipedia, Weather, GeoRSS, Panoramio, and other layers can be made clickable, but will not have information about individual articles or images. For this reason, markers cannot be grouped or filtered by subject, language, or any other properties.

[1]KML is the OpenGIS encoding standard (OGC KML) for managing the display of data in Google Maps.

[2]GeoRSS is a standard for encoding location in feeds of content, such as news articles, audio blogs, video blogs and text blog entries. See Chinese Canadian Immigrant Pipeline, 1912-1923 and Arrests of Italian Jews, 1943-1945 projects at the Center for Spatial and Textual Analysis (2013) or National and Regional Statistical Visualization at NComVA (n.d.). ed interchangeably.

## OVERVIEW OF POPULAR GEOSPATIAL VISUALIZATIONS

In this section, we review the most popular types of geospatial visualizations described in the literature. These types are not mutually exclusive; designers combine them. Although these geospatial visualizations vary in complexity, their designs share a common shortcoming: they are data-centered, not activity-centered.

### Geographic Information Retrieval Visualizations

Visualizations for geographic information retrieval usually have a simple conceptual design. Users interact with such visualizations by searching for spatial objects in certain locations and browse the retrieved results on a map. Such visualizations are often used to display news, library collections, real-estate listings, and retrieval results in geospatial search engines. They excel at making geospatial relationships visible: showing spatial diffusion, proximity, and relationships (such as overlaps, is-part-of, touches, and others). However, when the results are retrieved, these visualizations do not support the tasks that often are essential constituent parts of analytical reasoning and sense making activities. Upon retrieval, users usually need to perform further actions and tasks, such as gather, group/regroup, transform, filter, compare, and annotate. Retrieval visualizations seldom support these user-needed actions and tasks.

### Time Maps

Cartographers and geovisualization researchers have developed several conceptualizations of time and space (e.g., Peuquet, 2002; Hägerstrand, 1982; Andrienko, 2003; Kraak, 2003). Whereas in simpler time maps, visualizations are based on linear time models, in more sophisticated spatio-temporal models, visualizations are based on a space-time cube (Kraak, 2003). Simple time maps show changes in objects both on a map and a timeline, and are favoured by digital humanists, linguists, and health and earth science researchers (for an example, see CSTA, 2013). In the cube model, the x- and y-axes form a map, the z-axis represents time, and events and processes are projected onto x-, y-, and z-axes accordingly. Since this model is rather complicated, it only has a few implementations (see, e.g., Huisman et al., 2009).

Geographic time (i.e., time that can be observed on a map) has many different conceptualizations including world time, valid time, user-defined time (Peuquet, 2002), absolute time (universe time), cyclical time, ordinal time, and time analogous to distance (Vasiliev, 1997). In some real-world activities, a frame of reference for time is not geographic time, and users have alternative models of time and space. For example, in narratives, people discretize space and events in time by the objects and the events in time. They connect representations of space and time by segments, temporally in the case of space, causally in the case of events (Tversky, 2004).

Simple time maps can represent time in the form of text, a bar, a clock, or a combination of these, where users can interactively switch between them (Edsall, 2001). Edsall also describes a "time coil" representation that resembles a telephone cord with linearity along its length and cyclical behaviour in the coil (Edsall, 2001). Peuquet (2002) suggests that time can also have branching lines for overlapping periods.

Time maps can help users answer questions about the existence of objects and their locations in space, as well as the existence of events and their duration, frequency, sequence, or location in time (Edsall, 2001; Kraak, Edsall, & MacEachren, 1997). Users can select objects, times, or locations, and observe how objects change over time and compare phenomena (Andrienko, Andrienko, & Gatalsky, 2005; Plaisant, 2005). None of these provide mechanisms for performing for elaborate interactions to support higher-level activities.

### Maps with Dynamic Queries

Dynamic query interfaces allow provide users with the ability to formulate queries by directly manipulating and adjusting of sliders which results in immediate, dynamic display of found information items (Williamson & Schneiderman, 1992). These interfaces show continuous visual representation of information objects. Sliders represent values of the properties of the entities in a database, and visual entities in the displayed visualization area are a subset of the entities from the database. Such geospatial visualizations help users dynamically locate information items, filter unwanted information, detect trends, and notice exceptions (outliers). However, these are only basic tasks.

### Coordinated Displays

Coordinated displays focus on the visualization of multiple properties including geographic space and time. Representations in coordinated geospatial visualizations include synchronized geospatial maps, semantic views, and timelines. They can facilitate spatial data mining and discovery of patterns and trends (Guo & Mennis, 2009), help maintain situational awareness (MacEachren et al., 2010), and assist knowledge construction (MacEachren et al., 1999). An example of coordinated displays is the Health GeoJunction web portal (GEOVISTA Studio, 2007), which has a digital map synchronized with a Tag Cloud and a timeline. All individual views (the map, Tag Cloud, and timeline) are generated from the entire collection of documents, and represent the collection from different perspectives (i.e., it is easy to establish relationships between representations of entities in one view with different representations of the same entities in another view). These displays highlight relations among properties, including geographic space, time, and topics, and can provide comprehensive overviews of the data from different perspectives (Andrienko & Andrienko, 2007). As such, change to any of the properties in one display affects the representations in other displays and causes them to get updated. For example, a change in a range on a time slider causes simultaneous changes in the Tag Cloud and on the map. These visualizations are suitable for making sense of the spatial distribution of objects and their properties, but are less useful for non-spatial information. Problems include lack of screen space and complex, cognitively overwhelming and counterintuitive interfaces (Baldonado et al., 2000).

The geospatial visualizations described in this section can display rich data layers, in which objects can be grouped, selected, transformed, sliced, and divided. These design models support visual, retrieval, and exploratory tasks; however, they generally fail at assisting users to carry out more complex real-life activities.

## TASKS, ACTIVITIES, AND INTERACTIONS

Activities and tasks are best understood in the context of Activity Theory (Kaptelinin & Nardi, 2009). Activity Theory offers a conceptual framework that accommodates diversity along a number of dimensions. This theory not only accounts for higher-level activities, real-world interactions, and work contexts, but also integrates technical, cognitive and social perspectives. It proposes that activities are mediated by tools as well as users' interaction with tools. Activities, tasks, and interactions are defined next.

### Activities

As we mentioned earlier in this chapter, human activities refer to "clusters of actions and decisions that are done for a purpose" (Saffer, 2010, p. 35). Examples include real-estate decision-making, exploratory data analysis, disease monitoring, and knowledge discovery[3]. Each of these higher-level activities relies on a number of smaller actions and decisions carried out in tasks (Sedig & Parsons, 2013).

### Tasks

Tasks are conscious processes undertaken in the fulfillment of a goal. They can be recursively broken down into subtasks. For example, finding neighbours in a space, measuring distances or estimating travel time.

### Interactions

Interactions refer to low-level actions that users perform on objects and the responses of those objects, which enable users to adjust information to suit their epistemic, cognitive, and contextual needs and preferences (Sedig & Parsons, 2013). Interactions enable different properties, elements, relations, and layers to be probed, made explicit, and available on demand, thereby making the visualizations better suited to the needs and preferences of users (ibid.).

Activities consist of tasks and interactions in a given context; however, they are more than their sum. Rather, they are purposeful and planned by subjects through interaction with the environment (Kaptelinin & Nardi, 2009). For example, when planning a trip to a new destination, users study maps; learn the history of the location and its landmarks; find a place to stay and eat; estimate and measure distances to places of interest; create itineraries; make changes to their itineraries when they start the trip and get a better understanding of distances and the environment, and so on.

## AN EXAMPLE OF A HUMAN ACTIVITY

In this section, we illustrate the limitations of data-centered designs (described in Section 3) through an example of a human activity in the context of real-estate decision-making.

Data-driven visualizations for real-estate decision-making are typically designed as maps augmented with dynamic queries or as geographic information retrieval tools. Examples of mashups can be found at http://www.realtor.ca/, http://www.housingmaps.com, http://www.realtor.ca/, and other web sites. These visualizations typically answer questions about distances and housing properties, such as how far this is house from work or grocery stores, how long it takes to get to school, how big the house is, and how many bedrooms the house has. But real-estate decisions are not only about distances and time. Decisions are made by a variety of stakeholders performing a wide range of activities. Stakeholders include home buyers, renters, builders, brokers, bankers, business analysts, and public agencies. Oftentimes these people are interested in much more than properties and distances for their decisions. These decisions require information which is unavailable in real-estate listings.

In general, real-estate decisions can be divided into corporate and residential. In corporate real-estate decision-making, location, interior design, space layout, lease obligations, nearby amenities and complementary facilities all play a decisive role (Gibler, Black, & Moon, 2002). Schmenner (1982) further identifies labour costs, potential for labour unionization, proximity to markets, supplies, and resources, and concerns for quality of life. Plaut and Pluta (1983) and Bartik (1985) add business climate, employment, and services to the list, and further, Rabianski, DeLisle, & Carn (2001) identify labour force, income and other taxes on corporations, fees, changes and special assessments, development regulations and controls, utilities and infrastructure, public and transportation services, cost of living, and community as factors influencing decision-making about corporate real-estate.

Corporations also take aggregation of related businesses and industries into account, as it leads to greater cross-firm synergies and improved supply-chain management (Rabianski, DeLisle, & Carn, ibid.). The importance of agglomeration is demonstrated by Shilton and Stanley's study (1999), which found high geographic clustering among Fortune 500 firm headquarters. Some firms relocate to cities with high labor supply and low cost of living (Alli, Ramirez, & Yung, 1991), while others seek to reduce costs without compromising growth or sales (Manning, Rodriguez, & Ghosh, 1999).

Concerns in residential real-estate can be grouped along the following activities: (1) planning, (2) construction and development, (3) finance, including construction lending, property taxation, and assessment, (4) property management, (5) risk management, (6) marketing, and (7) regulatory compliance (Peterson, 1998). Residential real-estate buyers and sellers often use information not available in visualizations. For example, Northcraft and Neal (1987) observed that real-estate buyers make 'comparison computations' by assessing the number, age and condition of comparable properties, those already sold in the area, and other potential buyers. Similar characteristics of real-estate sellers within a neighborhood also tend to have like effects on real-estate transactions within that geographic area (see Can 1992; Dubin 1992; Can

& Megbolugbe 1997). A summary of factors affecting real-estate decision-making can be found in Zeng and Zhou (2001), who distinguish among environmental, social and personal factors. Environmental factors include slope, elevation, vegetation, parks and natural reserves, rivers and beaches, floodplains, dump/hazardous sites or other pollution. Social factors include demographics, housing prices and proximity to shopping centers, railway stations, schools, hospitals, theatres, roads, bus stops, railway, power-lines and airports. Lastly, personal factors refer to income, place of work, location of relatives, household size, value of mortgage, and preferred population group.

Other stakeholders, such as business analysts or real-estate agents, may also be involved in real-estate tasks and activities. For example, real-estate analysts look at changes in the spatial diffusion of prices to identify the origin and spread of bubbles (Roehner, 1997), while real-estate agents utilize storytelling, a task for marketing properties and communities.

Prior to map application programming interfaces becoming widely available, a few geographic information systems designed in the 1980s and 1990s attempted to support some of the aforementioned tasks and activities (see Belsky, Can, & Megbolugbe, 1996; Thrall & Amos, 1996; Barnett & Okoruwa, 1993; Beaumont, 1991; Hall, 1993; Thrall, Fandrich, & Thrall, 1995). These systems facilitated tasks and interactions that helped users make well-informed decisions about real-estate properties. For example, Francica (1993) and Kochera (1994) describe applications that allow users to determine whether a property is located in an area prone to natural disasters (e.g., floods or earthquakes) and calculate rates based on neighborhood crime rates, and distances to fire hydrants, fire stations, and police stations. Other applications allow users to access detailed site measurements and sales data, project population trends, identify market areas, estimate their potential, and measure their penetration (Robbins 1996; Rodriguez, Sirmans, & Marks 1995).

Nowadays, however, these tasks and activities are not supported by data-centered geospatial visualization designs. Data-centered visualizations support visual, exploratory, and analytical tasks about houses, estates, and rental properties, but largely exclude information about natural disasters, crime rates, distances, historical sales data, demographics, population trends, and natural or man-made features. This failure can be ascribed to at least two things. First and most important is the lack of designs that take into account human activities. Second is that, even though there is a tsunami of data, the data is scattered and difficult to collect in one place. In the next section, we present some considerations about task and activity-centered design and propose it as a means of improving time maps, coordinate displays, dynamic query interfaces, and other geospatial visualizations.

## ACTIVITY-CENTERED DESIGN CONSIDERATIONS

In this section, we discuss the advantages of activity-centered designs found in some mashups. Specifically, we examine the role of enhanced base maps, historical data, and storytelling techniques. These design considerations are not only useful for real-estate mashups, but also for various other activity contexts involving the use of geospatial visualizations.

### Enhanced Base Maps

The use of road maps as base maps in real-estate mashups provides limited support for making decisions about housing, since they contain no information about communities (e.g., crime rates, school quality, population trends, and demographics), environment (e.g., vegetation, parks and natural reserves, rivers and beaches, floodplain, dump/hazardous sites), or proximity to places of interest (e.g., shops, railway stations, schools, hospitals, theatres, roads, bus stops, and power-lines). The paucity of information contained in mashups persists, despite recommendations by some researchers (Francica, 1993; Kochera, 1994; Anselin, 1998)—this despite the fact that real-estate decision-making is an ideal area for designers to take advantage of Google Maps layers, Google Maps Styled Maps (Google Developers, 2012b), and other open source layers. For example, the Google Maps Demographics layer can provide information about population size, household income, marital status, age and race, while GeoRSS news layers from local newspapers can provide links to local news and police reports. Designers can assist users in understanding the environmental, cultural, and social affordances of locations by enriching base maps with various features (e.g., administrative, geographical, roads, and transit) and points of interest (e.g., attractions, businesses, government buildings, medical facilities, parks, places of worship, schools, and sports complexes). The OpenHazardMap layer, currently being developed as an addition to OpenStreetMap, can provide information about natural disasters (e.g., floods, avalanches, seismic activities, storms, forest fires, landslides, and volcanoes) and industrial disasters (e.g., dangerous material transport). Visualizations can also include KML layers showing boundaries of real-estate zones, giving buyers a better understanding of the extent of local communities, thereby making such visualizations more activity-centered.

Since geographical correlations between data layers and base maps can be made, designers may replace base maps with some other layers to help users carry out computational comparisons. For example, Matt Stiles, a journalist for The Guardian, has used an additional layer featuring "indices of deprivation" to demonstrate a correlation between riots and poverty in London, England. His map, shown in Figure 1, indicates the locations of riots with red markers mapped over the "indices of deprivation" base map. In this map, deep red areas represent higher degrees of poverty while blues indicate more income. This base map helps reveal the link between poverty and riot incidence.

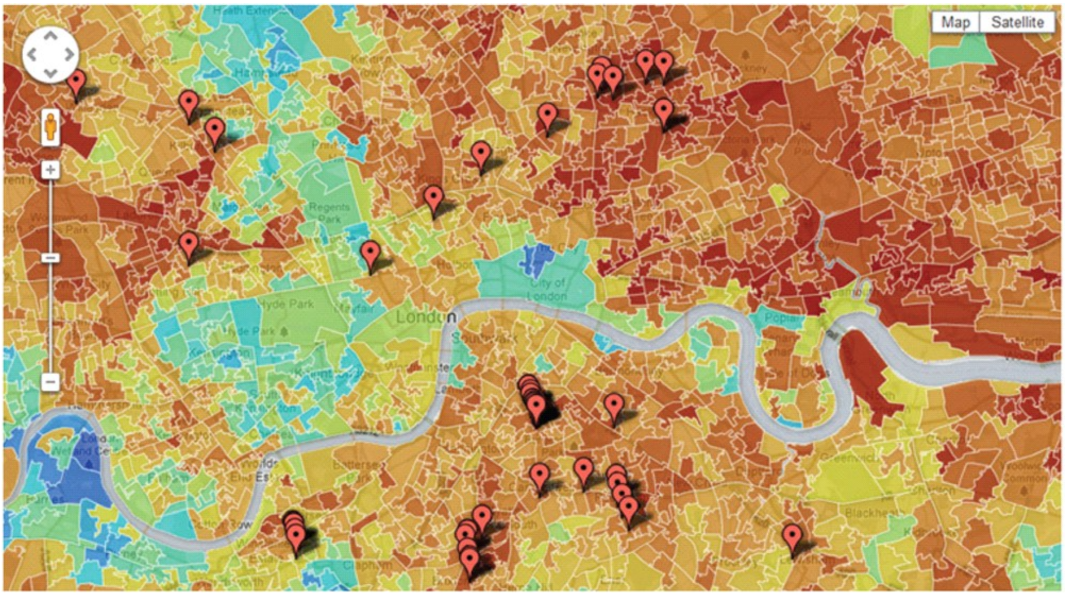


**Figure 1:** Map of London riots over ‘indices of deprivation’ base map.© 2011 Matt Stiles Used with permission

The ‘indices of deprivation’ base map can be used to highlight similar relationships in real-estate listings, helping buyers make extrapolations about houses for sale, depending on the level of income of neighborhoods.

## Historical Data

To further assist decision-making, geovisualization researchers suggest adding historical data, including proprietary records of project vacancy rates, rental rates, property appreciation rates over time, historical census data, and national housing survey data (Peterson, 1998). Despite challenges in finding and linking historical data to maps, there are thousands of GeoRSS layers, listings, and feeds that can be archived daily and used later for retrospective analyses. The archived data can form "sedimentation layers", a recent technique that progressively aggregates streaming data from feeds and generates and updates visualizations (Huron et al., 2012). These data can be used for the design of graphs and charts for individual locations, allowing the development of sales dashboards for real-estate zones.

Additionally, historical information can be discovered in historical maps in library collections, commonly residing on library servers, and largely neglected in geospatial visualizations. For example, real-estate maps can utilize Fire Insurance maps as their base maps. These are large-scale print maps that encode detailed information about real-estate properties, including outlines and exterior types of buildings, housing numbers, parcel lot boundaries, locations of windows and doors, street names and widths, and various landscape features. Architects, realtors, urban planners and developers, environmental assessors, genealogists, geographers, and historians often use them to understand the historical use of a parcel of land, assess property taxes, or estimate the damages incurred by natural disasters. Pictured below is The Sanborn Fire Insurance map for Reno, Nevada, dated April 1899. It shows the commercial center of the city, including the railroad tracks and train station, several hotels, a variety of businesses, most of which were constructed in brick (encoded in pink), "China Town" on the Truckee River, and legal houses of prostitution labeled "Female Boarding" (description adapted from Library of Congress, 2010).

A short comparison of Figure 2 to the aerial photograph of the same area in Figure 3 reveals that the railroad tracks, train station, and the Truckee River are still present, but the "China Town" and the "Female Boarding" houses are replaced with a plaza (across from Reno City Hall), Men Wielding Fire Restaurant, and Choque's Construction company. Hence, the fire insurance map helps users understand how Reno has changed over time and highlights the usefulness of insurance maps in understanding the history of real-estate properties.

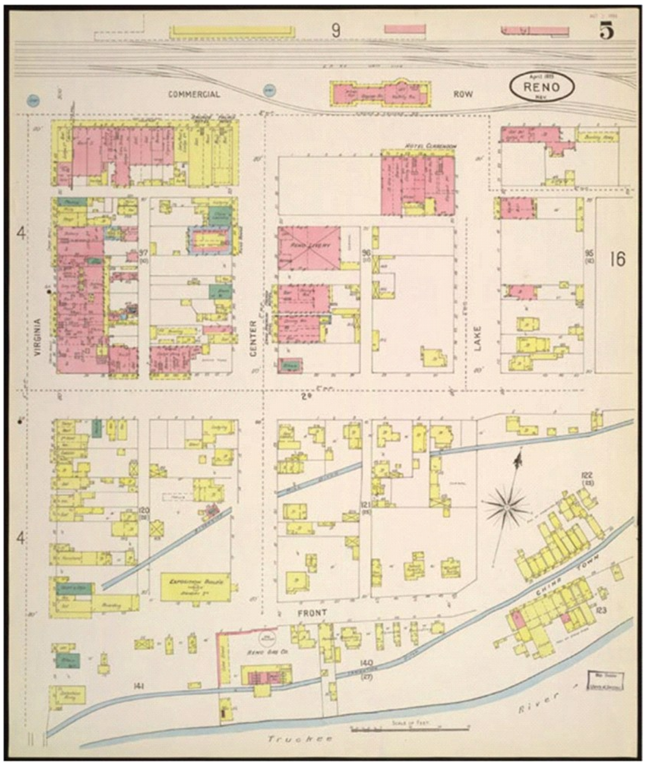


**Figure 2:** Sanborn Fire Insurance Map for Reno, Nevada, April 1899


**Figure 3:** Aerial view of Reno, Nevada, in Google Maps, December, 2012

Studies report that real-estate buyers often have questions about the history of a parcel of land prior to purchase, in particular, property lines, Indian reservations, historical property occupancy and use, and watersheds (Elias et al., 2008). Adding insurance maps to such visualizations can help real-estate buyers answer these questions, hence making them more activity-centered.

An example of how historical maps can be used with map application programming interfaces can be found in the mashups created by the Cartifacts company (e.g., http://maps.cartifact.com/lany/). The Cartifacts mashups for New York and Los Angeles merge historical maps with the modern maps by allowing users to interact with the map through a magic lens tool (see Figure 4). As users move the lens over the map, the historical layers appear on top of the modern maps. This technique offers many benefits to users. It allows for different representations to be correctly aligned relative to each other, hence preserving the geospatial relationship between the two maps. It enables users to relate features between the two maps by their spatial positions. It also enables users to control the focus by reducing the number of objects that fit into the lens. Ultimately, it allows users to learn local history of estates from historical maps, saving them a trip to a library or an archive.

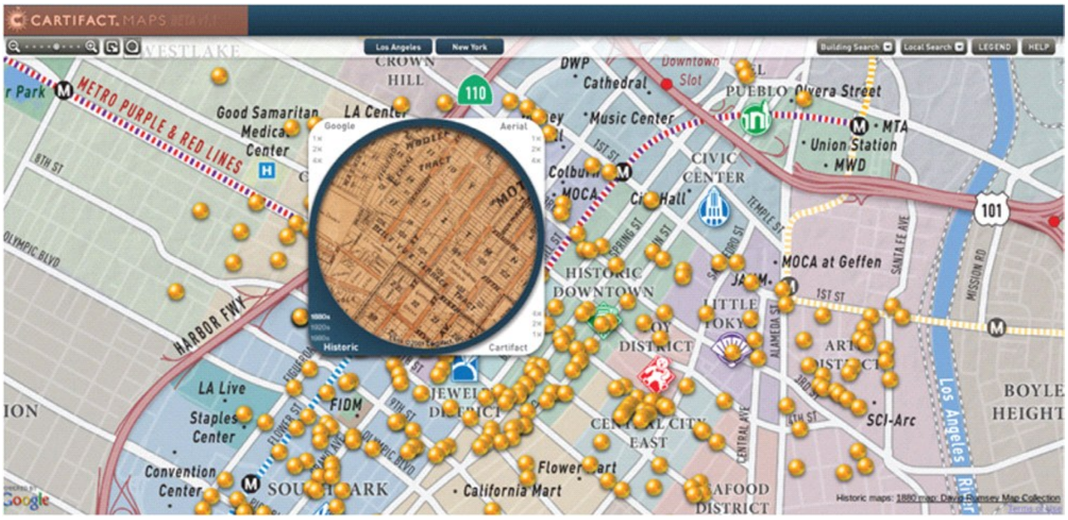

**Figure 4:** Cartifacts mashup with the magic lens © 2009, Cartifact, Inc. Used with permission

Putting print maps in the context of geospatial visualizations can be challenging, however. The problem is that print maps are characterized by varying orientations and projections suitable to the scale, locale, and terrain of the map. For this reason, it is difficult to align locations on historical maps with locations on digital maps. To overcome alignment problems, designers can use tools such as Georeferencer (http://www.georeferencer.org/) that can help adjust projections and orientations of scanned maps.

## Stories

Stories are essential for content marketing, organizational decision-making (O'Connor, 2002; Fleming, 2001), knowledge sharing (Sole & Wilson, 2002), and other higher-level cognitive activities. Stories can guide users through "unknown territories" and help them understand the relationships among entities in a geographical context (Cartwright, 2009).

Although maps can facilitate storytelling (Turner, 2006), data-centered geospatial visualizations often fail to communicate their affordances, including where users should start and the kinds of discoveries that are available to them (Andrienko & Andrienko, 2007). Despite being interactive, they are insufficient for understanding stories about changes in data because they do little to highlight related facts, events, or other layers of information to users. Without these relationships cognitive activities such as drawing conclusions, generation of hypotheses, decision-making, sense making, knowledge discovery, and understanding physical landscapes, are weakened (Isbister & Doyle, 1999).

Visualizations that facilitate storytelling use techniques that are often overlooked in data-centered design. These include Graphic Scripts (Monmonier, 1989), movies (Cartwright, 2009), interactive tours, narratives, and metaphors (Cartwright & Hunter, 1999). Graphic Scripts are series of representations and text statements that guide users from one information source to another, ensuring no essential information is missed. Such metaphors as The Storyteller, The Navigator, The Guide, The Sage, The Data Store, and The Fact Book allow for designing different scripts (Cartwright & Hunter, 1999). For example, the Guide takes the user and leads him or her to important and relevant information. The Navigator describes the map's role as a tool to assist users in finding where information is located. The Sage connects the user to experts in the field. The Data Store and the fact Book link to additional information about locations. The Storyteller tells users a multimedia story about local history.

Unlike timelines or other sliders used in data-centered visualizations, interactive tours do not force visitors to pass by all locations in a visualization, but guide them only through a series of selected destinations. Depending on the nature of users' tasks and activities, tours can be designed as geographical, trails, direct, attribute, or similarity walks. In attribute and similarity walks, users search for objects with similar attributes to those already selected (Card et al., 1999). Geographic walks can be based on alphabetic or geographic proximity of locations (Cunliffe et al., 1997), while tours can take different forms: users can walk, fly (Sedig & Sumner, 2006), navigate by a 'magic' subway, via warp drives, worm holes (Dieberger, 1994; Kay, 1990), or ocean currents (Benyon & Höök, 1997). The choice of mode of navigation in tours depends on the tasks and activities of users. For example, those planning a trip might choose a flying mode while geologists exploring the Earth's core would investigate holes drilled at the ocean floor.

Figure 5 shows a snapshot from 'The March on Washington' Tour in Historypin (Historypin, n.d.). Historypin differs from traditional data-centered collections of images of space and time in that its purpose is to "lead users step-by-step through a series of pieces of content, telling a story, exploring a place or walking through time" (Historypin Team, n.d.). The timeline visualization is activity-relevant and helps users establish historically relevant spatial relationships and match locations between the Street View in which they are immersed and the photographs superimposed upon it. To understand how a location has changed over time, users can change the opacity of the photograph overlay. This interaction helps users identify differences and similarities between old photographs and a recent Street View, locate historical landmarks on modern maps, and pinpoint modern landmarks on the historical backdrop. For example, while the photograph in Figure 5 below shows a crowd in front of the Washington Monument, in the Street View it appears to be gone, as the name Odeon does not appear on it.

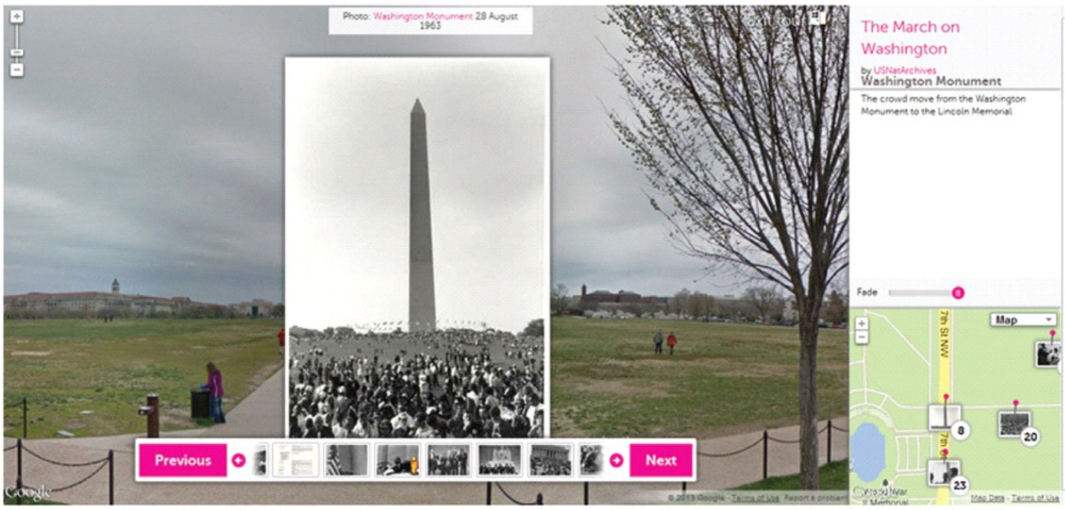


**Figure 5:** A snapshot from ‘The March on Washington’ Tour by US National Archives featuring ‘The Washington Monument during March on Washington’ (NARA identifier 595342) shared on Historypin.com by the US National Archives © 2013 Historypin Used with permission

All elements in the tour are linked to a navigation ribbon that guides users to the next step. Users can click on the thumbnails on the ribbon or use ‘Previous’ and ‘Next’ buttons to walk through the tour. Each element in the tour has its own description and explanation of how it is related to the rest of the tour.

The difficulty of integrating stories into geospatial visualizations depends on the granularity of the stories, which, in turn, is contingent upon user tasks and activities. Story details can be created at the macro and micro levels. Macro stories focus on entire cities, nations, or even the world, while micro stories narrate a particular part of a city, including communities, ethnicities, genders, or individual residents (Ball-Rokeach, Kim, & Matei, 2001). Stories can be user-generated or can come from layers. For example, the Wikipedia layer has numerous macro and micro stories about locations. The challenge is to understand how to relate and overview these stories. Despite the challenges, stories are useful for many tasks and activities and when added to data-centered visualizations can make them more activity-centered, and hence more human-centered.

## CONCLUSION

In this chapter, we have discussed data-centered geospatial visualization designs and how they often fail to provide enough support for real-world human activities of their users. The main problem with such designs is that their primary focus is the data layer component of the visualizations. This layer usually allows users to perform visual and exploratory tasks facilitated by access to gazetteers and metadata. By doing so, such data-centered designs often overlook other real-world high-level activities that users need to perform, such as geographical correlations, complex decisions involving historical data, and storytelling. Examples in this chapter demonstrate that these activities and their constituent tasks and subtasks often require interaction with additional representations (e.g., base maps, historical data, and other information), without which users cannot process or understand trends and patterns in geospatial visualizations. Therefore, when conceptualizing activity-centered visualizations, it is crucial to take the following into consideration: 1. Account for information representations and interactions; 2. Pay proper attention to additional information sources that help people draw conclusions, make decisions, and solve problems, and 3. Understand how people link and process information. Equally important, we need to open up possibilities for research to investigate what additional information and interactions should be combined in activity-centered designs. Such research can help visualization researchers better understand the conceptual principles for design of geospatial visualizations.

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## KEY TERMS AND DEFINITIONS

**Activities:** Human activities refer to clusters of actions and decisions that are done for a purpose.

**Activity-Centered Visualizations:** Activity-centered visualizations, not only represent the data layers, but also focus on users' needs, and real-world tasks and activities—such as storytelling and comparing data layers with other information.

**Base map Layers:** Base map layers contain geographical reference information upon which the data layers may be plotted for purposes of comparison or geographical correlation.

**Coordinated Displays:** Coordinated displays visualize multiple properties of the data layer. Representations in coordinated geospatial visualizations include synchronized geospatial maps, semantic views, and timelines.

**Data-Centered Visualizations:** Data-centered visualizations are primarily focused on representation of data from data layers.

**Data Layer:** A data layer consists of points, lines, and polygons, typically used to characterize distinct entities such as houses, roads, or districts.

**Geographic Information Retrieval Visualizations:** Visualizations for geographic information retrieval. Users interact with such visualizations by searching for spatial objects in certain locations and browse the retrieved results on a map.

**Geospatial Visualizations:** Geospatial visualizations are digital geographic and/or spatial maps to which users or designers can link their data.

**Google Maps Layers:** Examples of Google Maps layers include Wikipedia, Demographics, YouTube, Panoramio, Weather, and Bicycling layers, which enhance base maps and enrich users' understanding of location.

**Tasks:** Tasks are conscious processes undertaken in the fulfillment of a goal.

**Time Maps:** Maps with timelines.

## ENDNOTES

1. KML is the OpenGIS encoding standard (OGC KML) for managing the display of data in Google Maps.
2. GeoRSS is a standard for encoding location in feeds of content, such as news articles, audio blogs, video blogs and text blog entries. See Chinese Canadian Immigrant Pipeline, 1912-1923 and Arrests of Italian Jews, 1943-1945 projects at the Center for Spatial and Textual Analysis (2013) or National and Regional Statistical Visualization at NComVA (n.d.). ed interchangeably.