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An Evaluation of Web-based Geovisualizations for Different Levels of Abstraction and Realism – What do users predict?

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Abstract. Web-based geovisualizations are produced and served in various levels of abstraction (or realism) such as two-dimensional (2D) cartographic maps, aerial and satellite maps, shaded relief maps, three-dimensional (3D) objects integrated with 2D base maps, and digital globes with fully textured realistic 3D representations. All of these are necessary; but which one is best fitting for which task? When do we need the highest level of realism, and when can or should we use the highest level of abstraction? To contribute to tackling these large questions, we study a subset of non-expert tasks selected from task taxonomies in literature in relation to a subset of existing geovisualizations by means of two online user studies. In an online survey, users (n=106) responded to a list of tasks, where we ask them *to predict* which of the visualizations they think they would use for this task (thus we measure *perceived preference*). In a second survey, we give the users (n=245) a set of tasks *to solve* using one of the provided visualizations, thus we observe which level of abstraction/realism they will actually use and measure *actual preference (choice)* as well *performance*. In this paper, we report the results from the first survey.

Keywords: Abstraction, Geovisualization, Online maps, Realism, User studies

1. Introduction

Geographic visualizations ('geovisualizations' from now on) commonly 'assign' real-world objects and phenomena to abstract symbols for representing spatially referenced data, e.g., a square could mean a building or a park, a line could mean a road or river, or a drinking glass could mean a bar or a cafeteria. For geovisualizations to be functional at all, finding effective visual metaphors and identifying the right level of abstraction/realism are among the most important tasks. Identifying the right level of abstraction/realism is a multifaceted, complex and more importantly *unsolved* issue in geovisualizations (MacEachren 2001), we simply do not yet have established knowledge and/or guidelines as to when to use a highly abstract visualization and when to use a highly realistic virtual reality representation. In this study we tackle an aspect of the abstraction-realism issue with the overreaching goal of defining which levels of abstraction in web-based geovisualizations are suitable for which geographic tasks, particularly tasks which are executed by the general public (non-expert tasks).

2. Levels of Abstraction and Realism

2.1. Abstraction as a cartographic legacy

Cartographic maps are considered to be the earliest form of geovisualizations. One of the main goals of cartographic maps has been to identify and document the location of real world objects as accurately as possible. To achieve this goal, one of the many tasks is to make decisions about representation. This includes a set of decisions on the level of *abstraction* which is widely studied in cartography (e.g., Bertin, 1983, Robinson et al., 1995, Peterson, 1999, Slocum et al. 2001) and is considered to be a core element of the map-making process. As opposed to the cartographic tradition, it seems that in many visualization tasks, it is commonly (and perhaps often naively) considered that the more realistic a presentation is, the more helpful it is (Hegarty et al., 2009). Definitions of the term of geovisualization often include a spectrum of abstract to realistic representations (MacEachren, 2001; MacEachren & Kraak, 2001, Slocum 2001) and methods and techniques have been developed in this domain for creating realistic virtual environments (Batty, 2008; Peterson, 1999).

2.2. Realism and its components

Abstraction and realism are two ends of a spectrum of possible geographic visualizations. In the most realistic end of this spectrum, we can find virtual reality representations where the goal of the visualization is to mimic the reality as closely as possible. Such representations are often visualized in photo-realistic manner and should facilitate conditions similar to direct observations when studying a phenomenon. A number of researchers in the geographic information science, cartography and geovisualizations domains such as Heim (1998), MacEachren et al. (1999) offered systematic definitions of virtual reality and its components. Among these we include the definitions of some prominent considerations below.

Information intensity (level of detail): According to MacEachren et al. (1999) information intensity is the amount of detail with which objects and features are represented in the visualization. This concept is also called level of detail in geovisualization and certain other disciplines where natural and artificial landscape visualization is needed (Coltekin, 2006). It cannot be stated that a geovisualization is more realistic if it presents a high intensity of information. The visual objects must have just the right amount of detail that actually corresponds to what we expect from a real world object.

Immersion: The term refers to the sensation of being in the environment, to feel surrounded by it and to perceive it as a whole (MacEachren 2001). Therefore a geographic visualization is considered close to reality if it facilitates immersion. The key research problem is not to create reality-like full-immersive environments but to identify the specific characteristics of displays that can lead to the sensation of immersion.

Intelligent objects: In geovisualizations, intelligence of objects indicates the extent to which the displayed objects are having context sensitive behaviors (MacEachren ,1998).

Interactivity: Interacting with representations and objects is a key factor which distinguishes geovisualization from traditional cartography (MacEachren, 2001). Interactions in virtual worlds might not exist in real world, such as changing the color of the grass, making the sun and shadows invisible, analyzing data from different angles or in multiple views. Current body of research does not offer conclusive insights on how level of interactivity and level of realism correlate, but it can be observed the literature that they are closely related and influence each other.

Dimensions: A geovisualization can be 2D, 2.5D, 2.75D, false-3D, pseudo-3D and quasi-3D or true3D. These are often confused by the designers and not visible at first sight by the users, but each dimension has its own description and can be clearly distinguished based on mathematical equations and attribute definition (Wu Lixin et al., 2003). 2D is often associated with abstraction and 3D with realism; however, each level of abstraction can be associated with either dimension (Figure 1).

2.3. Levels of abstraction and realism

For this study, various online map providers were evaluated as candidate test platforms. We have decided to use Google Maps not only because it is (probably) the most popular map service provider, but it also offers more levels of abstraction compared to the others (Figure 1). These were defined based on some of the components listed in Section 2.2. (Table 1).

	Dimension	Information intensity	Interactivity
Map View	2D (no elevation data)	changes when zooming	panning, zooming, searching
Map View with WebGL	2.5D (+height, shading)	yes (changes with zooming)	panning, zooming, searching
Terrain View	2.5D (+height, shading)	yes (changes with zooming)	panning, zooming, searching
Satellite View	2D (no elevation data)	various resolution (changes)	panning, zooming, searching
Street View	fake 3D (with enhanced navigation)	does not change	enhanced navigation, only graphic zooming
Earth View	3D (with enhanced navigation)	various level of detail (changes)	panning, zooming, searching, tilting, rotating

Table 1 Factors of abstraction and realism in the Google Maps views.

The following interaction possibilities are the same for every two-dimensional view: panning, zooming (content zooming), changing the views, searching for a location. In Street View and the three-dimensional Earth View tilting/ rotating of the surface is added. Since immersion depends mainly on display size and type used to view the geovisualizations, this factor will not be discussed.

Map View: This view is the closest to the traditional paper map. It is two-dimensional, because no data about elevation is included, not even with the help of coloring (shading). In the Map View cartographic abstraction is applied: streets are colored lines, but their widths do not correspond to the widths of the streets in real world (generalization), buildings are represented by their perimeter and have the same color (grey). Similar to traditional maps the color of green area (forests, parks), water and urban area correspond to their natural colors, which somewhat enhances realism of these objects. Like in the real world the information intensity (level of detail) changes whit zooming in and out (getting closer or further away from an object).

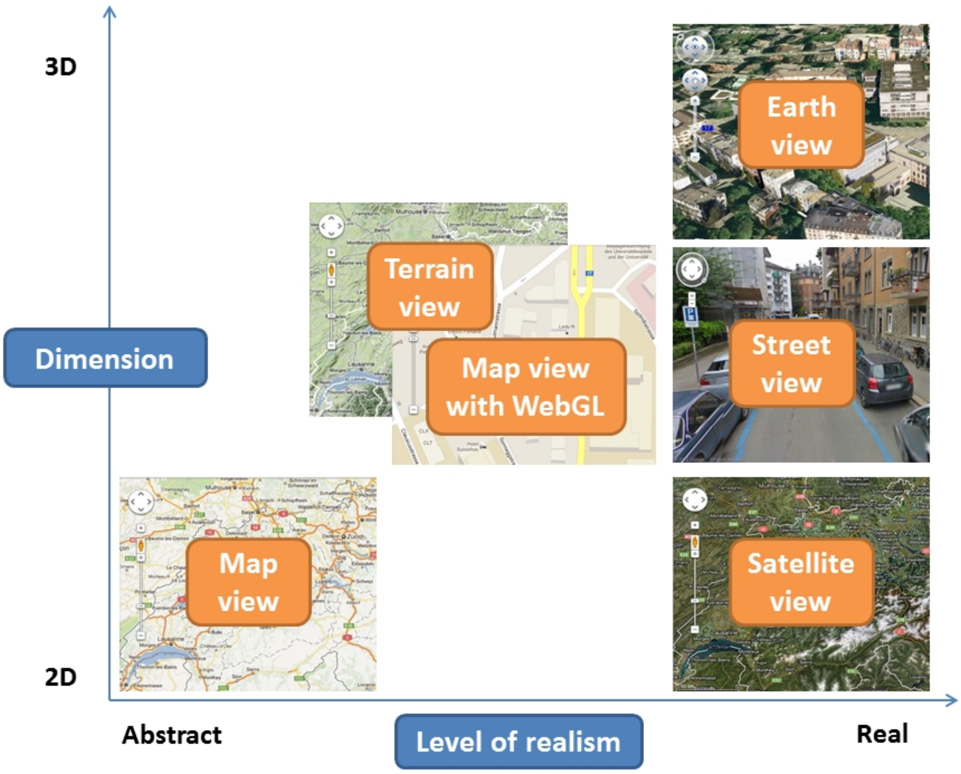

Figure 1 Ranking of Google Maps views according to level of abstraction and dimension.

Map View with WebGL: This view is a mixture of map and city block model. To the 2D surface of the Map View (described above) buildings were added. This is also called a grey block model whit simplified shapes of the buildings and heights assigned to it. These buildings seem to be three-dimensional, because they have shaded projections. This way the height and shape of the buildings are visualized and the representation seems more real. The view has limited interaction possibilities, it is not possible to rotate or tilt the view, like in three-dimensional visualizations. This is why the view can be categorized as being in 2.5D.

Terrain View: In this view heights are visualized in the landscape with the help of coloring and shading. Elevation is represented by different shades, which gives an idea about heights and shapes. Additionally contour lines of heights are drawn as well. This is a digital form of the shaded-relief method applied in traditional paper maps. Like in the reality flat regions (plains, valleys) covered by vegetation are green, mountain regions are grey and white (indicating rock and snow). This adds to the realism of the visualization. Same type of visualization can be found in the “Road View” of Bing Maps.

Satellite View: In this case the map surface is created from satellite imagery and is therefore realistic. Similar to Map View it is two-dimensional and has labels. Streets, borders, names of settlements, buildings and other informational layers are added on to the satellite imagery. These features can be switched on and off. This view integrates satellite imagery with various resolutions to visualize more or less information when zooming.

Street View: The 360-degree street-level imagery and the enhanced navigation create the feeling of being in a 3D environment, but Street View pictures are 2D representations and this is why they can be referred to as "fake" 3D. Street View appears only in the highest zoom level of Map View and Satellite View. Zooming within Street View is possible, but without any changes of information intensity. For higher immersion an anaglyph version of some of the Street View image is available (thus making it or "pseudo" 3D), which can be displayed by turning on the stereoscopic 3D mode, but to see the 3D effects special glasses are needed. Street View is realistic.

Earth View: The only true three-dimensional view in Google Maps has not only reality-like landscape representations, but photo-textured city models with different levels of detail as well. Tilting and rotating facilitates immersion in the environment, especially at street level. The buildings can be viewed from every angle like in the real world (different from the Map View with WebGL).

All of these web-based geovisualizations with various levels are necessary for certain geographic tasks which will be categorized in the following section.

3. Classification of geographic tasks

A complete taxonomy of geographic tasks would be beyond the scope of this study. Thus, for this project, a subset of non-expert "everyday" tasks are selected where maps or other types of geovisualizations. The selection process is based on Carter's (2005) classification and can be seen below:

1. Self-location (where am I)
2. Locating objects (where is a town, mountain, building, address)
3. Route planning (which route to take when going from A to B, planning before the journey)
4. Real-time navigation and way-finding (which route to take when going from A to B, planning real-time)
5. Identifying places of interests (where to do what)
6. Communication (present ideas, support ideas, education)
7. Storage of information (with spatial reference)

8. Virtual tourism (explore a place)

These tasks are developed into more specific questions and tested with various levels of abstraction and realism, with the help of an online survey designed to measure the predictions of the map users (perceived preference).

4. Online user study

The purpose of the survey was twofold: 1) we wanted to measure people's perceived preference for a certain level of abstraction/realism to later match this with the actual preference in a follow-up study 2) we wanted to 'harvest' geographic tasks that we did not think or and/or find in the literature for non-expert use of such range of displays. The tasks were analyzed in relation to a set of geovisualizations with defined levels of abstraction. The participants could choose any number of tasks (multiple-choice answer) for the given visualizations.

4.1. User study design and implementation

The survey includes a set of geovisualizations with different levels of abstraction and realism provided mainly by Google Maps. The Road View from Bing maps was used instead of the Terrain View, because the shaded relief was more visible. The following levels of abstraction and realism are used in the online survey:

1. Map View (2D abstract map with different zooming level)
    - Paris, France (region);
    - Zurich, Switzerland (street level);
2. Satellite View (2D realistic map) - Zurich, Switzerland;
3. Street View (fake 3D city model) - Cluj-Napoca, Romania;
4. Road view, Bing Maps (2.5D terrain model) - The Alps, Austria;
5. Map View with WebGL (2.5D city model) - New York, United States;
6. Earth View (3D realistic city model with different LoD)
    - Zurich, Switzerland - lower LoD;
    - Venice, Italy - lower LoD;
    - Barcelona, Spain - higher LoD;
7. Earth View (3D realistic terrain model) - The Alps, Switzerland;

Participants chose which tasks (multiple-choice) can be associated with each of the geovisualizations above. The task types are defined based on the classification presented in Section 3. In addition, the participant information, e.g. age, gender and level of education, self-reported levels of familiarity with geovisualizations is collected.

All the proposed geographic task categories were listed under example geovisualizations of a different level of abstraction/realism. The participants were asked to select the tasks that they thought were appropriate with the type of geovisualizations that they were looking at. They could chose more than one task per geovisualization (Figure 2).

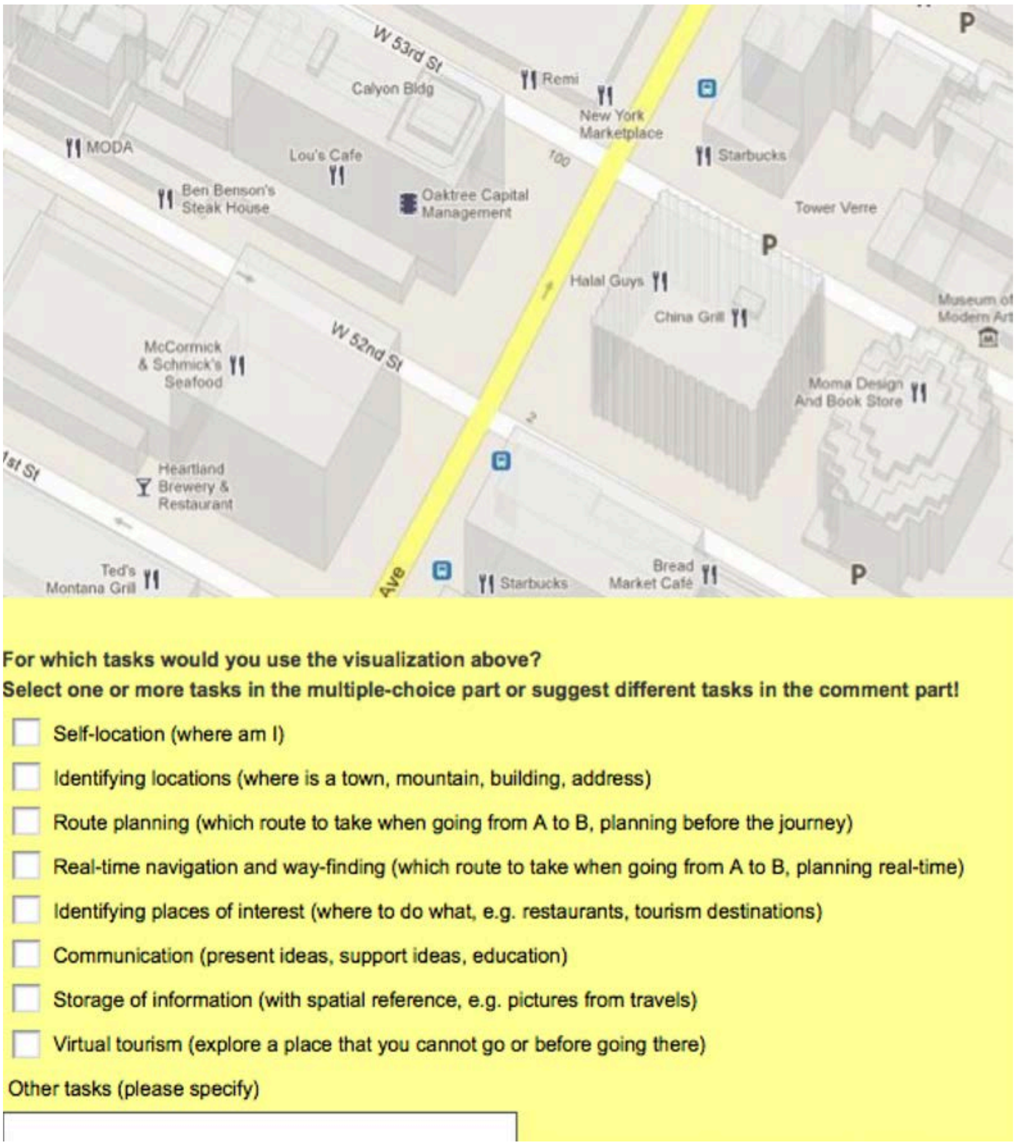

Figure 2. An example question from the online survey.

At the end of each question, the participants could also add what was not in the list, i.e. write in a text box additional tasks for which that they would use the presented display (Figure 2). The responses is recruited and analyzed with the help of an online survey platform.

4.2. Results

106 participants responded to the survey. After filtering out the incomplete surveys and those filled out by people with visual impairments, 90 participants remained and the analysis was conducted with n=90. The participants were of all ages with the majority between 21-40 years. The participants were roughly balanced based on gender (male 50.6% and female 49.4%). The majority of the participants possessed a diploma of higher education: 44.7% finished Master's degree, 34.1% Bachelor's degree or equivalent. The familiarity with geovisualizations ranged from not at all familiar (3.5%) to extremely familiar (17.6%) with the majority indicating a moderate familiarity (38.8%) with geovisualizations. Nearly all participants use geovisualizations during travelling (95.3%), majority use them at home/ in the office (68.2%) and half of the participants use them when walking, driving or in public transportation. They also indicated using geovisualizations during various outdoor activities, like hiking, biking, skiing or sailing.

The results are summarized in the table (Table 2) and the chart (Figure 3) below. The table presents which level of abstraction and realism is predicted for use (perceived preference) with certain geographic tasks. The highlighted numbers show the choice of the majority of the participants. We can observe that the participants predict using the abstract 2D visualization mainly for route planning tasks (74.4%) and for locating objects (61.8%). The 2D realistic view is also associated with route planning and object location and more than a half of the participants (53.9%) thought they would use it for self-location. Participants predict that they would use 2.5D city model (55.7%) and the 3D realistic visualizations (landscape and city models) mainly for virtual tourism tasks (68.10% and 72.10%). The 2.5D terrain model is preferred for locating objects and for route planning, for e.g. planning a hike or a bike trip. The majority would use the fake 3D visualization for identifying places of interest (87.6%). The chart (Figure 3) presents the categories of the common geographic tasks and the corresponding percentage for different levels of abstraction and realism. Overall, participants predict that for self-location and locating objects, they would use mostly a 2D abstract map, and for route planning both 2D abstract and realistic visualizations. The majority of the participants would use the 2D realistic, rather than 2D abstract visualization for real-time navigation. Identifying places of interest is associated more with 3D abstract visualizations. For communication, storage of information and virtual tourism, 3D visualizations were indicated to be most suitable.

Tasks/ geovisual-izations	2D abstract (Map)	2D real-istic (Satel-lite)	2.5D land-scape (Terrain)	2.5D city (Map with WebGL)	Fake 3D city model (Street)	3D realistic city (Earth)	3D realis-tic land-scape (Earth)
Self-location	42.20%	53.90%	26.70%	10.20%	41.60%	26.87%	18.60%
Locating objects	66.70%	60.70%	64.40%	36.40%	41.60%	38.37%	32.60%
Route planning	74.40%	61.80%	45.60%	8.00%	30.30%	13.60%	17.40%
Real-time navigation	33.30%	49.40%	23.30%	6.80%	23.60%	17.37%	11.60%
Identifying places of interests	32.20%	46.10%	20.00%	36.40%	87.60%	40.43%	10.50%
Communi-cation	18.90%	23.60%	18.90%	25.00%	9.00%	21.43%	30.20%
Storage of infor-mation	13.30%	21.30%	16.70%	25.00%	12.40%	22.17%	23.30%
Virtual tourism	22.20%	30.30%	22.20%	55.70%	16.90%	68.10%	72.10%

Table 2 Perceived preference for levels of abstraction and realism for the predefined task categories

The categories of gender, age and familiarity with geovisualizations were included in the analysis. No significant gender differences were identified in this survey. In the clear majority of the cases the primary geographic task associated with the levels of abstraction and realism chosen by the male and female participants was identical, with a single exception which we have not further analyzed. While some differences in the results between the age groups were observed, no persistent pattern emerged. The majority of the participants (between 21-40 years) agreed on the primary choices per visualization. Analysis gives early indications that for virtual tourism, storage of information, communication and identifying places of interest, people predict that they would prefer more realistic visualizations. For the first three

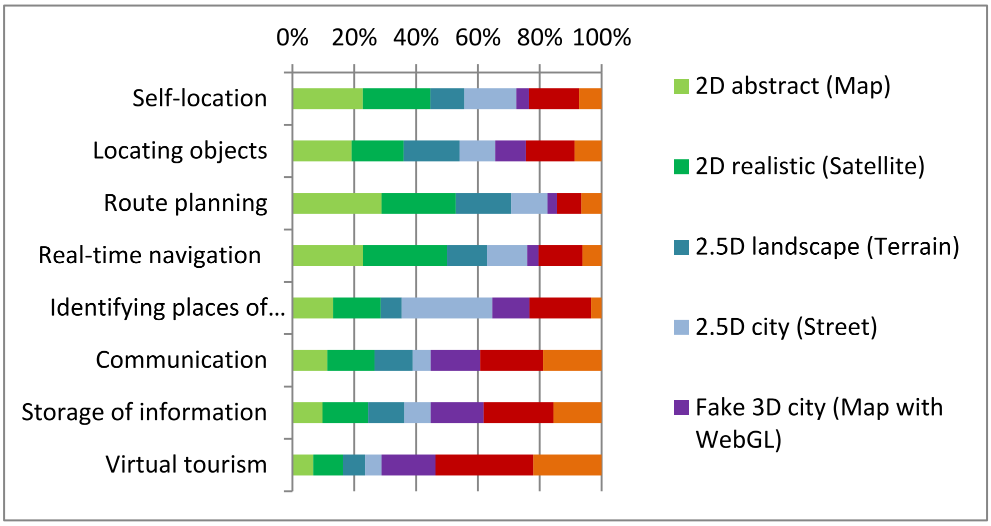

Figure 1 Summarized percentage of the perceived preferences

categories (self-location, locating objects and route planning), people think they would use more abstract visualizations. In most cases the participant groups based on familiarity with geovisualizations have chosen the same primary tasks, especially for 3D visualizations. They associated virtual tourism with realistic 3D and identifying locations with the 2.5D landscape model.

5. Conclusions and outlook

The overarching goal of this project is to identify which levels of abstraction are suitable for which geographic task. To narrow the task, we focus on common everyday (non-expert) geographic tasks and various levels abstract and realistic geovisualizations that are served for public use. In the study, as a first step, we investigate what people predict that they would use (perceived preference), which was reported in this manuscript. The findings indicate that people perceive clear distinctions between different levels of abstraction/realism for different tasks. As a secondary finding, the results of the survey also suggests that the task categories we offered "top-down" based on literature possibly cover the entire spectrum of common geographic tasks executed by general public (participants did not add more tasks for which they would use the tested displays). In the second stage the actual preference and performance will be tested and compared to the perceived preferences measured and reported in this paper.

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