A Comparison of Measured and Perceived Visual Complexity for Dynamic Web Maps

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1. Introduction and Background

We present a study of complexity in dynamic web maps using a two-step approach and compare the results. First, we count *distinct object types* (measured complexity) and second, we design and deploy a questionnaire to establish user perceptions (perceived complexity). In a case study we test our approach using three web map services examined at five different scales: Google Maps (GM), Microsoft Bing Maps (BM) and Open Street Maps (OSM). Our findings demonstrate an overall agreement between the two measures.

Complexity is a difficult term to define as it can arise from many different aspects of a visualization or a map and may vary based on the intended application (Olson, 1975). MacEachren (1982) wrote broadly on this topic and suggested two types of map complexity: *visual* and *intellectual*. Visual complexity is a direct consequence of the spatial distribution of the graphic content of the map and is concerned with perception and/or cognition of the information. Intellectual complexity, on the other hand, deals with meaning, that is, how the symbols are understood and what are their significance to the map audience (Brophy 1980, MacEachren 1982). Previous work on quantifying map complexity has relied heavily on mathematical analyses of basic object geometries to assess complexity of graphics. Consequently, many studies have tested the visual complexity of simple vector maps (choropleth, isopleth or line) using measures of vertices, edges and face numbers (MacEachren 1982, Muller 1976, Dietzel 1983). In a GIS context, Egenhofer et al. (1994) considered the number of nodes and arcs in maps in order to evaluate topological inconsistencies of objects across multiple representations in GIS databases.

Despite the abundant literature on the topic of graphic aspects of visual complexity, little has been done to assess user perceptions of complexity and how well these perceptions match quantitative measures. In a recent study, Harrie and Stigmar (2009) found that the metrics *number of objects*, *number of points* and *object line length* had better correspondence with human judgment than *object area*. Forsythe (2009) also evaluated different measures of complexity and demonstrated that many complexity metrics were biased by a familiarity effect; unfamiliar images were rated as more complex by viewers than by automated metrics. In an earlier study that deals with human perceptions of the visual complexity of photographs, Oliva et al. (2004) report that visual complexity is inherently multi-dimensional, resulting from a combination of factors such as quantity of objects, clutter and variety of colors. Other studies also exist that have evaluated the impacts of visual complexity on cognitive and emotional processing for websites (Tuch et al. 2009, Harper et al. 2009).

These studies, however, do not work with cartographic input, thus we observe a gap between highly abstract (hence, complex) geospatial information visualizations and perception studies. This paper contributes to the efforts to fill the gap, presenting a comparative study of measured and perceived cartographic complexity for dynamic web maps across a range of scales.

2. Measured Complexity

A previous quantification of map complexity based on counting the total number of displayed objects was proposed by Harrie and Stigmar (2009). We seek to expand this work by counting not the number of objects, but the number of *distinct object types*. This is because we hypothesize that perceived complexity is controlled not by the total number of objects and their spatial distribution, but by the total number of different shapes, colors and sizes that must be stored in short-term memory. Supporting this hypothesis, visual working memory is reported to hold about three objects at a time (Ware 2008), and objects with multiple features are not treated as separate entities but stored as single combined objects (Luck and Vogel 1997). In our categorization, whether an object is 'distinct' or not is based on three of Bertin's visual variables (Bertin 1974): *shape* (e.g., cartographic symbols), *size* (e.g., labels) and *color* (e.g., vegetation). The measured complexity for every map is based on a manual count of every object that is distinct in one or more of these three categories. Object types are further grouped into classes such as roads, labels, transport, etc. For each input map, we studied five levels of detail (five different scales) and for each level we counted the distinct object types. To maintain consistency and to control the level of possible human error, the same person did counts for all the images.

The five maps used for complexity measurements were chosen across a range of scales in order to maximize the difference between each image. The maps are all centered on the city of Zurich and are relatively large-scale images, ranging from a scale of about 1:6'500 to about 1:190'000.

3. Perceived Complexity

Using the same input maps and levels of detail as for the object counts, an online questionnaire was designed and deployed to assess the user perceptions of complexity. The questionnaire has a standard structure: after a welcoming page which also explains the objectives of the study, the participants' background information (such as age, gender, level of expertise) is queried. Following this, participants are asked to rate the selected stimuli based on a 5-step Likert scale. The ratings vary from "too general" (not enough information) to "too complex" (too much information in one display). Responses are collected for *within* different scale levels of a stimulus and *between* stimuli. In a following step, two control measures are used: stimuli are manipulated to create a 'grayscale' set (minimizing the effects of the color variable and focusing on shape, size and value) and a 'blurred' set (minimizing the effects of the shape and size variables and focusing on color).

4. Results

At the time of this writing, 13 participants (6 male and 7 female, average age 26.5) have responded to the questionnaire. All participants use web map services (WMS), e.g., for getting directions (69.2%) or finding an address (84.6%). While the majority of participants (61.5%) are *very familiar* with GM, and *just familiar* with OSM (53.8%), 69.2% reported that they were *not familiar* with BM. In Figure 1, the results of the user survey and the manual object counts are plotted on the same axis to compare changes in complexity over a series of five scale levels. Object type counts are normalized from nine to five for comparison. The curves show that, overall, *measured complexity* and *perceived complexity* have similar trends. *Perceived complexity* is displayed both in *mode* and *mean* and *measured complexity* is the total object count for each scale.

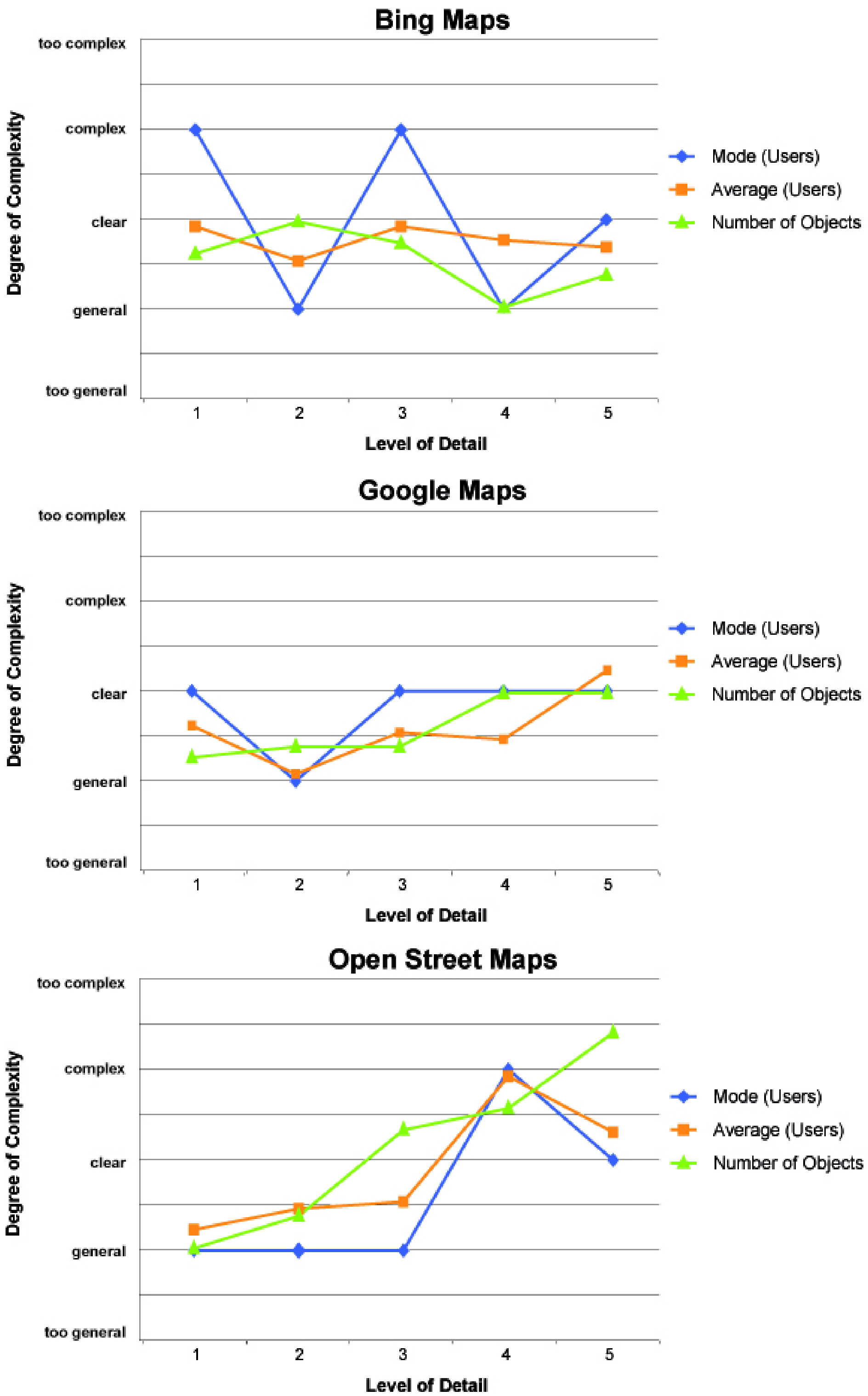

Figure 1. Curves comparing the two measures of complexity.

Complexity for both measured and perceived averages (in Figure 1, lines that are marked as “Average (users)” and “Number of Objects”) tends to rise as the zoom level increases. Especially for the OSM a much steeper increase is can be observed in comparison to the GM and BM. The best match between curves is for GM, a result which may be affected by user familiarity with the map service.

5. Conclusions

Due to the low number of survey participants at this point of the study, these results are only preliminary. Nonetheless, they provide an indication that user perceptions of complexity may be correlated to the total number of distinct object types visible on web maps. Additionally, this pattern can be followed over a range of scales, indicating that the total number of displayed object classes does not affect the ability of the user to select a complexity level that matches the “measured complexity”. With further elaboration, findings from this study may help guide decisions regarding level of detail in real time generalizations of dynamic web maps. A follow publication expanded from this study with a larger number of participants and a more in-depth analysis is in preparation.

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