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ABSTRACT

The presentation of search results in GIS can expose the user to cluttered geographical maps, challenging the identification of relevant information. In order to address this issue, we propose a visualization model supporting interactive information filtering on 2D/3D maps. Our model is based on the introduction of transparency sliders that enable the user to tune the opacity, and thus the emphasis, of data categories in the map. In this way, he or she can focus the maps on the most relevant types of information for the task to be performed. A test with users provided positive results concerning the efficacy of our model.

CCS CONCEPTS

• **Information systems** → Geographic information systems; Search interfaces; • **Human-centered computing** → Visualization;

KEYWORDS

Search Results Visualization; 2D/3D Geographical Maps; Opacity Tuning; Visual Information Filtering

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1 INTRODUCTION

"Empirical studies show that visualization technologies, such as 2D maps and 3D virtual environments, can facilitate participants' learning and understanding in decision-making, especially spatial decision-making, processes" [16]; e.g., see [2, 25]. However, a map-based presentation of Geographical Information search results can overload users with the visualization of large amounts of data.

One way to face this issue is that of enabling the user to easily focus maps on the data relevant to the execution of the specific activities he or she is engaged in. In this work, we are interested in verifying whether user-controlled transparency of map content can be an effective tool for this goal. We thus pose the following research question:

RQ: *Can opacity tuning help the user focus on relevant information during the analysis of geographical search results, with respect to visualizing data with a fixed opacity, the same for every category of information?*

In order to answer this question, we developed an interactive information filtering model that enables the user to emphasize/de-emphasize categories of information in a map, by tuning the opacity of the shapes representing geo-data in a selective way; e.g., to make museums transparent, or semi-transparent. Our model provides sliders to tune the opacity of items by category. In that way, the user can steer visualization directly on the map, in order to let the most relevant information emerge, without losing reference to the other search results. Our goal is that of supporting a form of abstraction, through information filtering; see [9].

We carried out a laboratory test with users to evaluate our visualization model in the OnToMap Participatory GIS (PGIS) [6, 7, 27]. The results of our experiments show that opacity tuning is a powerful function to dynamically customize map content in order to satisfy detailed information needs, e.g., to temporarily focus on a subset of the search results relevant to the completion of a sub-task.

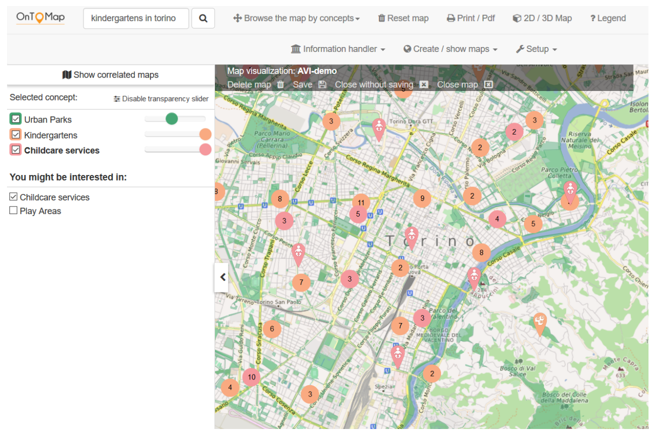

Figure 1: 2D map generated by OnToMap.

2 RELATED WORK

Many Web Collaborative GIS display information on 2D and 3D geographical maps; e.g., see [16–18, 26]. However, to the best of our knowledge, these systems do not enable the user to tailor the emphasis of information visualization.

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Some works attempt to reduce the complexity of geographical maps through abstraction. E.g., [28] proposes hierarchical route maps representing less or more detailed views. [12] varies the width of linear geometries to highlight the most relevant results. Other works exploit transparency to overlay different types of information on maps [21], to combine an attribute setting mechanism with the visualization of a background working area [14], to merge maps in an overlay model [13], or to provide translucent layers for map exploration [20]. In comparison, we employ transparency to enable the user to focus maps on subsets of information.

Visual interfaces are adopted in information retrieval to provide overviews [15] and help the comprehension of information [4, 5]. Some works present results by displaying them in 3D maps representing geographical, temporal, semantic, or other types of relations [11, 19, 24]. Other works reduce visual complexity through sketching [29]. We represent the geographic extension of information on maps, using a symbolic representation of data categories, in the tradition of Parish Maps and community mapping [23].

3 VISUALIZATION OF INFORMATION

Our model assumes that data is semantically modeled in categories representing more or less specific types of geographic information. The domain conceptualization is based on an OWL ontology that relates geographic information categories by means of specialization and thematic relations; see [7, 8, 27].

Figure 1 shows our visualization model for 2D maps, applied to the OnToMap PGIS. Different colors are associated to data categories for easy identification, and geo-data is depicted either as markers or as shapes (if the geometry is available) using the associated colors. The tab in the left portion of the page shows the categories selected by the user as checkboxes, which (s)he can de-select/select to quickly hide or restore information in the map. Behind each checkbox there is a transparency slider that supports the tuning of the opacity of the corresponding data items. For instance, in the figure, the urban parks are semi-transparent.

Figure 2 shows the 3D map. In this case, search results are depicted as solid, stylized, vividly colored shapes, corresponding to the colors of data categories, and are overlaid on the 3D terrain layer: they cover the corresponding objects, but they are stylistically different for discernibility purposes.

The user interface of OnToMap is implemented using HTML5 mark-up language + CSS, and uses (i) Leaflet[1] for 2D visualization based on OpenStreetMap [22], and (ii) Cesium [10] for the 3D map. The opacity of items, tuned by moving the sliders, is rendered in 2D by modifying the properties of the CSS. In 3D maps, the color *alpha* channel of the item object is updated using the Model-View-ViewModel (MVVM) pattern. See [3] for details.

4 EXPERIMENT

We evaluated our model in a laboratory test with users (54 people), using OnToMap (OTM), in 2D and 3D modalities, and we compared it with Google Maps (GM) 2D and 3D, representing the baselines.

We asked participants to perform 4 map-learning tasks, each one associated with a different map (OTM 2D, OTM 3D, GM 2D, GM 3D): in each task they had to look at the map and answer a question in which we asked them either to count how many items of a certain category were visualized, or to find a specific geographic item; e.g., an individual hospital. OTM outperformed GM in user experience, which we measured by means of two types of questionnaire: one after the execution of each of the 4 map-learning tasks, and a post-test questionnaire to collect feedback about the best and worst characteristics of OTM 2D and 3D. Specifically:

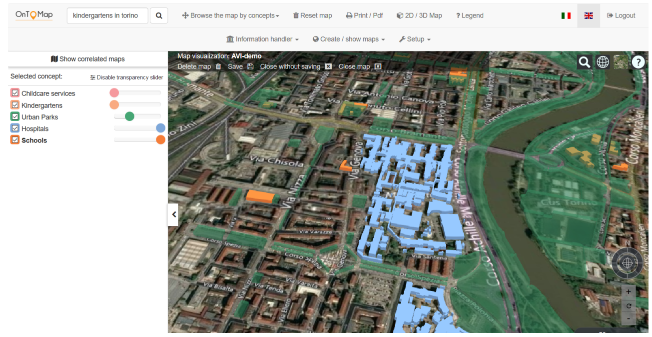

Figure 2: 3D map generated by OnToMap.

- In the comparison between OTM 2D and GM 2D, OTM received the best evaluations in terms of ease of use, ease of identification of information, attractiveness and novelty. Conversely, GM got the highest rating for the clarity of information visualization.
- OTM 3D outperformed GM 3D in all of the measures, except for the attractiveness of the map, which was challenged by the lower definition of OTM background layer w.r.t. GM one.

The post-test questionnaire confirmed that the best feature of OTM was the information filtering support provided by transparency sliders. People also appreciated the visualization of geometries, especially in 3D, because they help recognizing buildings in the city. Moreover, they liked the representativity of the icons of markers because they help discerning the type of information on the map.

In contrast, participants complained about the visualization clarity of OTM 2D, and in particular on the colors of the background layer of the map, which challenged the identification of some types of geo-data. Indeed, this observation is in line with the finding that participants provided the largest number of correct answers when they used Google Maps 2D, which probably means that they could identify data items in a clearer way.

Overall, the results of this experiment suggested some improvements to the user interface of OnToMap, but they positively answered our research question RQ by providing evidence about the efficacy of opacity tuning in information filtering.

5 CONCLUSIONS

This work focused on the impact of user-controlled transparency on the presentation of geographic information in 2D and 3D maps. We developed an information visualization model that enables users to emphasize/de-emphasize data in a map by tuning the opacity of shapes. We carried out a preliminary experiment to test the model with users. Our experiment revealed that transparency sliders are an effective tool to focus maps on specific information needs.
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