Venice Unfolding: A Tangible User Interface for Exploring Faceted Data in a Geographical Context

Till Nagel, Frank Heidmann
University of Applied Sciences Potsdam
Pappelallee 8-9, 14469 Potsdam,
Germany
{nagel, heidmann}@fh-potsdam.de

Massimiliano Condotta
Università Iuav di Venezia
Tolentini S. Croce 191,
Venezia, Italy
condotta@iuav.it

Erik Duval
Katholieke Universiteit Leuven
Celestijnenlaan 200A, 3001
Heverlee, Belgium
erik.duval@cs.kuleuven.be

ABSTRACT

We introduce Venice Unfolding, a case study on tangible geo-visualization on an interactive tabletop to enable the exploration of architectural projects in Venice. Our tangible user interface consists of a large display showing projects on a map, and a polyhedral object to browse these data interactively by selecting and filtering various metadata facets. In this paper we describe a prototype employing new methods to communicate territorial data in visual and tangible ways. The object reduces the barrier between the physical world and virtual data, and eases the understanding of faceted geographical data, enabling urban planners and citizens alike to participate in the discovery and analysis of information referring to the physical world.

Author Keywords

Tangible interaction, tabletop interface, geo visualization, urban planning, multi-touch, visual browsing, faceted data

ACM Classification Keywords

H5.2. [User Interfaces]: Interaction styles, Input devices and strategies, Prototyping.

INTRODUCTION

Work with geospatial data is routinely carried out in groups with users exploring the data in ways according to their different needs. Public participation geographic information systems (PPGIS) "usually call for an open-ended exploration in which users […] examine various issues that relate to their community and locality" [1]. In her literature review, Sieber [2] summarizes they "allow participants to dynamically interact with input […], and empower individuals and groups."

Instead of creating a PPGIS with all the possibilities complex GIS offer, we intended to develop a reduced but

user-friendly interactive tabletop visualization with a narrow focus on a specific data set to trigger discussions at town-hall meetings or urban centers. The aim is to support the decision-making process, and to allow active citizens and local stakeholders to impact the directions of their cities. We strived to create an explorative visualization to invite residents to participate in analyzing urban transformation and new projects, helping them to influence the ways limited amounts of money are spent in their territory. For that, we enriched the flux of information, composed of data about projects and conceptual relations between them, with geographic locations. And we tried to lower the barrier to access the data by implementing simple tangible interactions.

There have been several related studies. Ishii et al. [3] describe an Augmented Urban Planning Workbench, which combines physical and digital media for a more holistic design approach. Their conclusions suggest that this method shifts the emphasis away from computer screens by creating an integrated environment in which stakeholders can incrementally create shared understandings. Other studies investigated the utilization of tangible objects for spatial interactions on tabletops (e.g. [4, 5]).

In this paper, we focus on a prototype developed collaboratively by architects, urban planners and interaction designers. We conceived new methods to communicate territorial data in visual and interactive ways, enabling experts and non-experts alike to participate in the exploration and analysis of geo-located data. The paper discusses requirements and design decisions, gives an overview of the visualizations and interactions of the prototype, and concludes with first results of a usability evaluation and an outlook on future work.

REQUIREMENTS

We developed a list of specific requirements based on our previous experience in the design of visual exploration tools for architectural contents [6, 7].

- Users should be able to interact directly with the relevant information to be able to control several parameters.

- Navigation of the information space needs to be flexible, according to the choice of users.

- A subtle but permanent guidance giving visual feedback needs to be in place in order to prevent users from getting lost in open environments.

- People should feel invited to participate. The tool shall be social, not as personal and introverted as stand-alone desktop computers, but an open shared information space for collaboration and discussion.

- Size of the interaction space should be large enough to allow multiple users interacting with the visualization. Thus, enabling directed collaborative exploration, as well as to find connections by serendipity when different persons examine the data they are interested in, simultaneously.

In order to enhance knowledge exchange processes, the communication of conceptual networks has to be simple and visual: It allows users to intuitively grasp these conceptual networks increasing both their understanding and exploration activities. In turn, this enhances "analytical strategies for information seeking based on planning, query terms [such as through dynamic filters], and iterative adaptations of queries based on evaluation of intermediate results" [8].

PROTOTYPE

The Venice Unfolding application visualizes the spatial and conceptual relations of 116 architectural projects, enabling users to investigate the territorial transformation of the City of Venice. The prototype is built for a tabletop display, and shows a map as basis layer, which can be navigated by finger interactions. On the map, projects are displayed at their locations, with further metadata visible on demand. A physical object acts as tangible input device, and can be used to select various faceted data and filter the projects. In the design of the object we opted for a shape signifying the interaction possibility to select different facets, hinting to the literal meaning of a "facet".

Furthermore, we intentionally designed the object to create curiosity by being an interesting physical artifact to invite users to touch and utilize it. If users want to choose a facet, they tilt the object towards that area.

Figure 1. Projects displayed on a map of the City of Venice

The asymmetrical polyhedron consists of one base area and five responsive faces in different shapes, which act as filters to various facets of the data.

Metadata is faceted when it is composed of orthogonal sets of categories, allowing the assignment of multiple classifications to an object. Faceted metadata has been proven to support exploration and discovery [9].

For this prototype we employed facets relevant to architecture and urban planning, i.e. designer, date of construction, functional typology (such as "Infrastructure" or "Residential") and keywords. We picked these classification categories, as they can describe the visualized projects appropriately. For the latter two facets we utilized a subset (selected by architectural experts) of flattened classification terms from the hierarchical MACE taxonomy [10], to reduce the conceptual complexity while still enabling "semantic interoperability among contents" [7]. All facets are used to determine relations between projects based on shared metadata.

Technical setup

The interactive surface of the tabletop has an area of 1.87 square meters, and a resolution of 29.4 pixels per inch (full HD 1080p). As resolution strongly influences visualizations [11], this relatively low resolution led us to iteratively re-design the interface, e.g. by opting to only display three facet text entries in legible font sizes at a time. The table size enables multiple persons to watch and interact with the visualization, simultaneously. For more details on the construction and technology of the interactive table we refer to [6].

The polyhedral object is roughly 5×6×6 cubic centimeters. Each reactive face of the polyhedron includes a unique *fiducial marker* printed on the surface. The marker reflects infrared light recognized by a high definition camera inside the table, allowing the system to identify the currently faced-down polygon, as well as the object's position and orientation. This tracking procedure was developed with the reacTIVision framework [12].

Cartographic information depicted through the map comes from OpenStreetMap [13], while Cloudmade [14] provides the image tiles. This allowed us to embed interactive maps fast and effortlessly without the technical setup of a complete map server stack. While the main reason was to customize the map according to interface design necessities, one further advantage is users may contribute and update underlying spatial data. This crowd-source approach may encourage stakeholder communities to participate in discussing territorial problems.

Visualization and Interactions

In the beginning, the map of the whole territory is displayed with all projects represented as markers at their locations (see Figure 1). Users can zoom and pan the map to select an area they are interested (by pinching, respectively dragging

Figure 2. Interaction sequence with the tangible object, starting with a) selecting one of the facets, b) choosing a specific entry from the radial menu, and c) browsing through further metadata and media of a selected project.

it with their fingers). Tapping a marker (i.e. touching it with a single finger) selects the respective project and shows its background information and media files, as well as connections to related projects.

The main exploration activity is performed with the physical object, which allows haptic direct manipulation. To select a facet the polyhedral object can be tilted to one of its sides. The edges of the polyhedron are flattened, aiming for an effortless and easy-to-use tilting maneuver.

For the visualization of the data facets we used the metaphor of unfolding a 3-dimensional object, to support users grasping the concept of opening the data set from different perspectives, and "to present a broad overview of the entire collection and to allow many starting paths for exploration" [9].

The polyhedral object can be placed anywhere onto the table's interactive surface to begin with one of two interactions: (1) Select criteria to filter and display specific projects, and (2) Browse background information of a single project. When a user puts the object onto the tabletop, the facets are displayed, each represented as an unfolded face of the polyhedron (Figure 2 a). After the user tilts the object onto one of its sides, the entries of the chosen facet are displayed as a radial fisheye menu surrounding the object (Figure 2 b). The text items are alphabetically ordered and displayed as small ticks, thus visualizing the overall amount of items. By rotating the object the user can now browse through the terms. The currently viewed one is set in large type. Its direct neighbor entries are legible as well, while farther apart ones are blanked out due to space constraints. The user can choose a specific item by moving the object towards its text representation. After a user's selection, the application filters the data set, and highlights matching projects on the map. If necessary, the map section automatically adapts appropriately, so highlighted projects always fit the whole table surface.

After the user selects a single project, the radial menu around the polyhedron changes to offer background information. The three categories "description", "pictures", and "relations" are shown at North, East, and South

position so as to not interfere with the facet item selection (which is at West). Keeping the same interaction mechanism, users select a category by moving the object towards its respective orientation. By rotating the object inside the ring users can explore project information in detail: scrolling through the descriptive text, and browsing through explanatory pictures (Figure 2 c). Selection of the third category ("relations") activates the project's conceptual network with other projects (Figure 3).
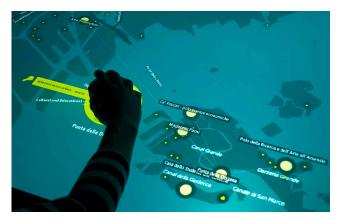

Figure 3. Exploring relations between projects

The possibility of showing related projects in a direct visual way is a key feature of the interface. The relations are based on common metadata, for example same designer, similar construction date, or sharing some conceptual classifications according to the taxonomy.

When the user selects this modality all corresponding projects are highlighted with their titles on the map, and can be selected to start a new browsing and discovery process through the information network.

EVALUATION

We conducted a formative user study to gather first feedback from users working with the prototype. We recruited four male and two female participants aged 22 to 40 years from the student body and non-research staff of the FH Potsdam. All participants were right-handed and with normal or corrected-to-normal vision. The participants all

ranked themselves technically savvy, and all but one had used multi-touch devices before. The participants were encouraged to think-out-loud, while the interviewers were writing down those remarks and their own observations. These sessions were recorded on video and took approximately 60 minutes each.

We asked the participants to execute specific simple tasks, and to fill out a post-test questionnaire on their satisfaction with the tool. The tasks ranged from finding projects of a given architect, to filter projects for a specified keyword, and to browse the media of one project.

While the map and the display of the projects were interpreted correctly, the polyhedral object was not immediately understood by all participants. For browsing through the alphabetical list, all users rotated the object in the opposite direction. Two users did not realize the selection mechanism, and tried to tap the appearing items with their finger.

After these initial errors all participants learnt the implemented interactions. Overall, the participants described the prototype as "playful", "inspiring", and "liked" the explorative approach, but criticized the tilting mechanism as not sufficiently self-explanatory.

CONCLUSION AND OUTLOOK

We presented a case study visualizing architectural projects in Venice. First results suggest the tangible interaction with the polyhedron reduces the barrier between the physical world and virtual data, and eases the understanding of faceted geographical data. The presented mechanisms look promising to be used in other domains with tabletop applications enabling users to explore various facets of a dataset in a unified visualization.

In the continuation of our research, we will incorporate the given feedback and refine the interaction design aiming to improve the usability. Currently, we are working on extending the polyhedron with an embedded accelerometer to be able to give visual feedback as soon as the user starts tilting the object, with the intention to ease the discovery of the facet selection mechanism. This also will allow us to provide object shaking as interaction pattern to clear the current selection.

Furthermore, we started first experiments in evaluating the prototype using head-mounted eye-tracking devices, and are planning to test the prototype with different sets of data to investigate whether our conceptual background assumptions are transferable to other domains.

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