

Browsing and Correlating Architectural and Territorial Data in Tangible Maps: New Knowledge Opportunities in New Learning Places

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Abstract. This paper discusses the learning and educational potentialities of the Venice Unfolding prototype, an experimental tabletop application designed to explore and investigate urban and territorial contents and knowledge. The prototype supports and transforms ways of approaching various strategies involved in urban and territorial planning processes. It creates new ways of viewing, understanding and learning about urban and territorial environments and leads to a more efficient examination of their underlying characteristics. In doing so, it fosters greater knowledge generation about their use, evolution and growth. In this paper, the authors describe the prototype's development, its fundamental concepts and its considerable instructional capabilities that have been piloted with educators and students.

Keywords: Tangible maps, urban planning, territorial information, knowledge organization system, tabletop application, geo visualization, learning.

1 Introduction

Architecture, urban planning and territorial management are sectors in which planning processes constitute a syntheses of efforts in which different knowledge fields, including the technical and the artistic, work together toward design solutions (c.f. [1]). The geographic areas and scenarios subject to the planning processes vary greatly, meaning that every planning process requires a preliminary study to adequately understand the specific environment. In other words, it is a process that needs and involves learning. Here, learning is intended as the process of acquiring new knowledge by processing different types of information. We refer to all learning that is goal oriented and driven by a motivation or a necessity as a learning process. This process can occur without conscious awareness, in contrast to formal conscious learning. In the following pages, we describe how our prototype supports such an unconscious learning process.

The Venice Unfolding prototype is an interactive tool designed to conceive and develop new methodologies to communicate urban and territorial data in visual and

interactive ways. It enables urban experts and non-experts, professionals and students alike to participate in the discovery and analysis of information located in physical and geographical space. It is intended to enrich development strategies in the various stages of the decision making and planning processes. Supporting new ways of viewing, understanding and learning about the urban and territorial environment can lead to a more efficient examination of its underlying data, thereby fostering knowledge generation and learning. Our goal is to improve this by proposing dynamic and flexible methods in gathering and evaluating architectural, urban and territorial data.

Visualizing large volumes of data, which is typical in these domains, presents a significant problem. People, especially non-experts, very often lack perception when presented with large amounts of untapped and potentially valuable data [2]. Various semantic visualization techniques and technologies have already focused on the expert-centric display of complex information spaces and ontologies. The novelty of our research is that expert perspectives are applied to help personalize a visualization of a learner's activity in a learning environment and to create knowledge opportunities through the conception of new pedagogically-rich learning paths. This enhances the learner's own understanding, performance and problem solving capabilities. Such expert supported visual insights have the potential to dramatically improve a learner's explorative reflection of their learning process.

In our research project we designed and developed a tabletop application that not only transmits information by the visualization of data itself, but also fosters further and unexpected outcomes by allowing the users to study and learn the inherent conceptual relations of the contents. The rich flux of information, composed of data about the projects and the conceptual relations between them, is further enriched by their juxtaposition in their geographic locations. The application visually combines the analysis of data features with the urban and territorial structure into a single information space. This creates a new way of reading and interpreting the urban text of a city, of the anthropized or natural environment. It moves the exploration activity towards a creative process of "experience multiplication" [3] by extending the number of possible navigation routes inside the dynamic network of contents, consequently increasing the quantity of discovered notions.

2 Conceptual Background Supporting Motivations and Objectives

The prototype was not developed with a specific and exclusive didactic aim, but rather, as supporting tool for knowledge processing related to the field of architecture, urban planning and territorial management. The basic idea that motivated this research was to support the processing of data related to a specific urban domain in order to improve the decision-making and planning processes of urban experts and non-experts. This ambition is based on two main assumptions.

First, it considers the human factor. It suggests that solving complex problems (such as those related to urban development) does not simply involve the sum of each participant's knowledge, but is rather the result of a process of knowledge exchange and knowledge creation embedded in social interaction. This social creativity can

serve as an input to improve decision-making processes and their related planning choices [4]. Additionally, this knowledge exchange can be stimulated by the involvement of the various stakeholders' in the community development, including average citizens. To enable this involvement, it is essential to improve the access to data for stakeholders and policy makers and to enhance their knowledge of the issues. A number of city administrators in this field have worked toward this end. In Venice a variety of well-attended exhibitions, meetings and web sites have been opened to citizens over the past several years, dedicated to illustrate the ongoing development of their city (e.g. [5]). Likewise, in the cities of Bologna and Torino, agencies have been established for creating public communication centers in which all the participants involved in city development (designers, citizens, public administrations, etc.) can meet in order to exchange and discuss the ongoing projects ([6], [7]).

The second assumption focuses more specifically on the activity of processing information to apply new knowledge to the planning process. The idea is that different levels of notions and concepts overlaid into a single information space can increase and support the urban design process and decision-making toward new ways of approaching complex design solving problems related to territory [8].

In brief, our goals are to:

- Stimulate and encourage collaboration and social creativity;
- Conceive new ways of simultaneously representing different kinds of notions in order to foster the creation of new knowledge.

2.1. Pedagogical aspects

In architecture and urban planning (as well as other disciplines heavily based on constant problem solving) learners self awareness of their learning paths and their ways of putting information together in a meaningful way is a significant part of the learning process.

An efficient way to acquire knowledge and, more importantly, to generate new knowledge, can be explained as follows:

- Any new knowledge builds on previous knowledge. Learning something new never begins from scratch. The learner has a wealth of earlier experience and previous knowledge that determines how he/she interprets new information and data. It is therefore important to know the basis of ones own conceptions and to have the opportunity to share them in an efficient way.
- Emphasizing comprehension through significant relations between notions is a meaningful way of building on our fund of knowledge. The ability to understand notions, discuss them intelligently and apply them, are closely related to each other. Once we understand a problem of an urban or territorial situation, we can discuss our conception of it and ask relevant questions about it. At the same time, applying our knowledge in practice through the elaboration of new and significant relations between notions, serves as a measure of our understanding.
- Learning is based on the learner's activity in the learning process. Learning something new is most meaningful when the learner is stimulated into a curiosity to learn and encouraged to be active in satisfying that curiosity. The role of the learner, therefore, is to be active and full of initiative. A learner's ability to

problem solve is not only intended to verify his/her acquiring an understanding of the material but also to demonstrate the capacity of using the significance of the contents to generate new knowledge.

- Social interaction has a central role in learning. Without the social interaction with other more knowledgeable people, it is difficult to acquire the meaning of important symbol systems and learn how to use them. With the Venice Unfolding prototype we can support and create flexible ways for people to interact through the application of technologies.
- Flexibility in training arrangements supports the learner's level of autonomy. It is important to create new ways of learning, ways that are as flexible as possible. It is also important that the new ways of learning and the consequent new learning paths are under the control (scaffolding) of experts in the field.

2.2. Collaborative information spaces in architecture and urban planning

There have been several studies over the last years utilizing tabletop interfaces in order to represent information, and to allow novel ways of tangible interaction.

Among them, the research project “Envisionment and Discovery Collaboratory (EDC)” at the Colorado University [4] studied the impact of socio-technical environments in support of learning, participation, collaboration and design and the “Augmented Urban Planning Workbench” called “Luminous Table” that experimented with and evaluated the combination of physical and digital media for a more holistic design approach [8]. Their outcomes and conclusions suggest that this kind of approach shifts the emphasis away from the computer screen as the focal point, and creates an integrated environment in which stakeholders can incrementally create a shared understanding through collaborative design. Another important outcome is that a successful design tool can stimulate creativity as well as help solving problems combining the benefits of multi-layered representation with the possibility for tangible interaction, and providing a platform for meaningful collaboration support.



Fig. 1. The interactive table with active users.

Moreover, following our study of the state of the art in the field of Urban and Territorial Planning, we believe the consolidated representation model is turning

towards an integrated system of territorial geo-referenced information. This allows a convergence of the various contributions from social networks and the layering of different notions into a single information space. Due to the ever-increasing demand of territorial and urban knowledge by stakeholder communities, architects, and urban planners, we believe that a continuous acquisition of new concepts, ideas, methodologies and technologies is absolutely necessary.

With the Venice Unfolding case study, we offer this area an improved set of visualizations and innovative user interfaces. Moreover, we have created an experimental research project to study and evaluate new methods of communicating spatial information.

3 Analysis Requirements

The prototype and its alternative applications that we have developed need to be characterized by certain features in order to best fulfill their purposes. Therefore, on the basis of the above mentioned conceptual notions and pedagogical models, on the basis of our studies of existing applications, and on the basis of our previous experience in knowledge management systems related to architectural and territorial field [3, 9, 10], we have developed a list of specific characteristics aimed at matching these goals that can be organized around the followings points:

- A friendly and direct access to data must be one of the key points of the interface. The user needs to interact directly with the information without difficult devices to control the several parameters involved. Also, the interaction elements needs to be intuitive, familiar and reasoned according to the cultural characteristics of the users (in our case familiar with the architects way of thinking and working).
- Navigation of information needs to be as flexible as possible and individualized to user's particular needs. A subtle, but ever present guidance has to give visual feedback in order to prevent the user from getting lost in the complex environment.
- To enhance the knowledge process and the overlaying of concepts, the relation network between notions has to be explicated in a simple, visual way that the user can grasp intuitively, thereby enhancing both the understanding of notions and the general exploration activity. As Rice et al. [11] suggest, this enhances the "analytical strategies for information seeking that are based on planning, use of query terms, and iterative adaptations of the query based on an evaluation of intermediate results." In fact, if the logical connections between results are visually displayed, the intermediate results are themselves self-explanatory and, in being so, provide an overview of the results. In addition, given also the fact that part of the information finding and access is based on browsing strategies (typically heuristic, opportunistic and associated with recognizing relevant information) [12] it is evident that the possibility of highlighting the logical connections and relationships between notions play an indispensable role in increasing the success of knowledge acquisition.
- Finally, an important aim is to create a social system, not something isolated and introverted as a stand-alone desktop computer, but instead an open space for

collaboration and discussion that increases and enhances the social creativity process.

3.1. The conceptual base of the tool: the city and the environment as an urban or territorial text

In order to be implemented, our aims and goals must be supported by a Knowledge Organization System (KOS) [13]. In our project, the MACE Application Profile (MACE AP), which enables “semantic interoperability among contents” [3], has been used as base to create the database schema of the prototype. Thanks to its formidable characteristics, it is possible to support the notions exploration activity according to the methodologies previously described, and to make explicit the conceptual relations between these notions. This KOS has been developed in the MACE project¹ and can be applied to our research as it shares with it the same theoretical and conceptual background. In ours, the anthropized territory as well as the natural environment can be considered as a text [10] - a sort of architectural or natural speech expressing its meanings through perceptible signs [1] that we are able to read with the right instruments.

The adopted solution, provided by a structure of semantic metadata from the MACE AP, has been to create conceptual categories by which to classify the various aspects of the knowledge objects that are the subject of the exploration activity. Moreover, this classification schema allows the generation of a network of reciprocal connections of the contents involved.

The use of the MACE AP as foundation is important for several reasons. First of all, it is based on several existing and shared thesauri. Second, the possibility of easily adapting the Tangible Maps systems to different specific domains since we can draw from various sections of the MACE AP covering all domains related to architecture, urban planning and territorial management. Finally, is important to recall that the MACE AP was developed to support educational scenarios and was itself based upon our previous experiences on distance and blend learning at IUAV using web based technologies. This is one of the main reasons that our prototype has such promising educational capability. From these experiences, we created a web based collaboration system called TDraw - Telamatic Drawing system², which is an asynchronous collaborative method organized as a virtual classroom in which students and professors function on different levels and share graphic files that can be corrected and annotated by the teachers and that can also be visible to students in the class. All communications and notes shared during the entire design activity are preserved. The signed/selected works, the typical errors and the exemplary solutions represent the greatest effort in teaching the generative process of a project, and can be considered as the core of knowledge transmission.

¹ The EU project “Metadata for Architectural Content in Europe” (MACE) consists of a Web information system that organizes and connects major architectural archives with architectural and urban planning data. (<http://portal.mace-project.eu/>)

² The TDraw system and its upgrade version Tlabs, has been operational since 2002-03 at IUAV and in the Faculty of Architecture and Engineering of Ancona. cf. [14], [15]

By the classification of the knowledge elements associated with the project and its formative steps, we have been creating a model of re-composition of the architecture complexity.

3.2. The Venice case study

To illustrate and describe the work done so far, we will now introduce and explain the tool developed with an existing knowledge base. It utilizes the dataset of the “Carta delle Trasformazioni Urbane”, a web based platform developed by the City of Venice cataloging all new urban processes (new building complex, infrastructures, environmental actions, etc. hereafter called “projects”) that are involved in the transformation of the urban and natural environment of the city. This scenario was chosen during our development phase to be used not only in order not only to test the tabletop application, but also, and most importantly, as a pilot case in which to scrutinize the requirements of its specific tools.

4 The Venice Unfolding prototype

Based upon the requirements, we designed and implemented a working prototype and created an interactive visualization for a multi-touch and object-tracking tabletop. As a case study, we selected the architectural and urban projects of Venice from the previous mentioned database. The projects data, which are already classified with geo-location and other metadata, have been manually organized and enriched with terms from the MACE taxonomy.



Fig. 2. The tabletop application showing projects in the Venetian region.

The prototype consists of an interactive tabletop, whose surface displays the map, and media, texts, and metadata related to the architectural contents, and of an interactive polyhedral object to filter and select. The table's dimension is 2.2 m x 1.7 m with a height of 1.0 m. It can be used by multiple users simultaneously, and allows

easy access for standing users (see Fig. 1). The object can be placed onto the table surface and is then used to filter and select various metadata by tilting it to one of its sides. The edges of the polyhedron are flattened, aiming for an effortless and easy-to-use tilting maneuver. On each active side of the polyhedron is a printed fiducial marker. This marker reflects an infrared light recognized by a high definition camera inside the table, which allows the system to identify the side as well as the object's position and orientation. This tracking procedure was developed with the reacTIVision framework [16].

The cartographic information shown within the map comes from OpenStreetMap [17], while Cloudmade [18] provides the image tiles. This allows an interactive map to be embedded quickly and effortlessly (i.e. without the technical setup of a complete map server stack). While the main reason for this was to customize the map according to interface design necessities, a further advantage is that users can contribute and update the underlying spatial data without difficulty. This crowd-source approach encourages stakeholder communities to participate more easily in resolving territorial problems.

In the beginning, the map of the whole territory is displayed with all projects shown as well recognizable markers at their location (cf. Fig. 2). Users can then zoom-in and pan the map by touching and moving it with their fingers to adapt the map segment to their specific needs. Tapping a marker selects the respective project and shows all related background information and media files.

The main exploration activity is, however, performed with the polyhedral object: a physical artifact that allows a haptic direct manipulation [19]. In the design of the object we opted for a shape that eases the interactive possibilities of selecting different facets, while also being a visually pleasing artifact that invites utilization.



Fig. 3. 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.

The usage of the object is twofold: First and foremost, to select criteria to filter and display specific projects. The object consists of a base area and five surfaces in different shape sizes that act as a data filter. The different sizes relate to the amount of data in every single facet (Fig. 3a). If the user wants to activate a filter he has to tilt the object towards that area. The flattened edges make the tilting easy. The user can select a conceptual category and then choose a single entry from all the terms in that facet, displayed in a radial visualization surrounding the object (Fig. 3b). After a user's selection, all the matching projects are highlighted on the map. The map

section automatically adapts appropriately, so all highlighted projects are continually displayed on the table surface.

The second approach is to browse background information on a selected project. The design of that menu is similar to the filter menu. The user can choose one of three categories of information by moving the object towards one of the sides of the ring. By rotating the object inside the ring, the user can explore the project in detail, either scrolling through the described text and the explanatory pictures (Fig. 3c), or activating the project's conceptual network with other projects.



Fig. 4. The connecting lines between architectural projects show the existing mutual relations between projects on the Venice island.

The possibility of showing the project's mutual relations in a direct and visual way (Fig. 4) is one of the major benefits of the interface. It is based on shared metadata, e.g. same architect, similar construction date or sharing the same conceptual classification according to previously mentioned KOS and allows the exploration of corresponding projects. If this modality is selected (according to the desired characteristic chosen by the user) all projects connected to the current project appear on the map. Each of these can then be selected to start a new browsing and discovery process. By shaking the object (as if it were the eraser commonly used by architects), all selections will be cleared allowing a new exploration of the information flux.

5 Tool Capabilities Compared with Educational and Learning Aspects

In deem this system is a very promising prototype application in the sector of urban/territorial information organization. During our startup and testing operations, we were able to test new methodologies in accessing and interacting with the data. In particular, the most promising characteristics are:

- Immediateness, that is the non-mediated access to information thanks to a natural representation of the concepts;
- The highlighting and the emphasis of the interconnections between data, objects and concepts based on a structured database of semantic metadata;
- The personalized browsing of notions creating learning paths based on associations of ideas;
- The simultaneous multi-user interactivity.

Overall, the prototype can be considered a non-conventional system to explore the urban and territorial knowledge; one that can trigger positive effects in the improvement of decision-making processes and related planning actions.

Following the initial evaluations and debates with university teachers and professional architects, we realized that, beside its enhanced learning features, the prototype characteristics themselves make it a didactic/educational tool that can offer a wide variety of possible improvements in formal learning contexts. These are some of its characteristics:

- The tool was created to be used both by expert and non-expert users. If we consider students as advanced users but still unskillful experts, their expertise level fits perfectly with the target of the tool.
- The overlapping of different levels of notions into a single information space - allowing the discovery of complex correlation between conceptual, physical, social and dynamic factors - has a high didactic value and, as demonstrated by [8], can "enable students to respond with a more informed design".
- Promoting cooperation in a didactic environment and fostering learning opportunities. The multi users capability of the tool encourages cooperation and collaborative exploration of notions. Users interact and work together to reach a common goal of individual comprehension as a result of a group effort [20]. Learning becomes collaborative and the teaching process is reciprocal.

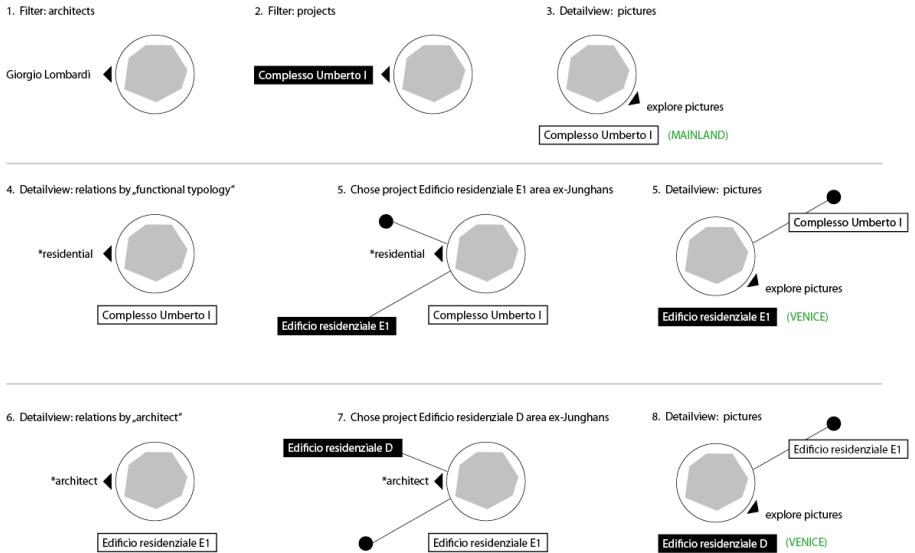


Fig. 5. Workflow of an exploration activity designed in the development phase. It represents a possible navigation route through concepts (in this case architectural projects).

- Making explicit the conceptual relations between notions enhances creativity and multiplies learning experiences [3]. In fact, conceptual relations increase the number of possible navigation paths that are suggested by the tool which surprise the user with their unexpectedness. This multiplication of possible learning experiences and the fact that the navigation path is not “fortuitous” but based on a theoretical conceptual base, is itself a learning opportunity, that is, a learning path. In Fig. 5 it is possible to see an example of how a workflow was created during the development phase to test the navigation possibilities through concepts allowed by the tool and to plan the interface design accordingly.
- The activity of implementing the tool’s database (information seeking and classification) can be seen as an important didactic moment. It is a process that needs a high level of understanding of the contents and therefore adequate preliminary study. If performed by students, it is a task that encourages them to examine the involved notions carefully and with a specific purpose. Moreover, the database’s tool, being based on a defined KOS that has been tested over a period of several years in an academic institution (previously described) has an important impact. In fact, it encourages users involved in the enriching of the database to read, analyse and thereby classify the contents according to a fixed and dedicated KOS taxonomy. That taxonomy has the characteristic of providing guided reasoning, one that possesses significant educational benefits as demonstrated in the tests performed during the MACE project evaluation [21].

Furthermore, we conducted a formative user study to gather initial feedback from users working with the prototype. We recruited four male and two female

participants, aged 22 to 40, 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 filtering projects for a specified keyword and browsing the media of one particular 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 understand the selection mechanism and tried to tap the appearing items with their finger.

After these initial errors, all participants quickly learned how to implement the 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.

5 Conclusions

We have shown how this tool can be used to support two different learning scenarios, as a lifelong learning tool and as an educational platform in academic education.

As an instrument used to approach problem solving and decision-making that enhances the learning and understanding of the urban architecture and territory, it can be naturally considered a lifelong learning tool. Its target users are not only professionals like architects and members of city and regional administrations, but also community members involved in city planning strategies.

As an educational platform, it revealed high potentialities for academic faculties of architecture, urban and territorial planning. It can be applied in several didactic scenarios, for example:

- In the study of cities and their evolving processes (as in the Venice scenario that was used to test the prototype);
- In the study of the elements composing the urban environment (buildings, squares, infrastructures, etc.);
- In the study of specific architectural trends inside a city, a territory, or a region;
- In the study of different aspects of an anthropized territory or of a natural environment involving several overlapping elements.

We can therefore affirm that, apart from its initial purpose and development, the tool reveals considerable learning and didactic capabilities. In fact, the learning capability is an intrinsic aspect of the tool as it is based on an unconscious learning process.

The characteristics of visual transmission of notions and their mutual relations as well as the direct and tangible interaction with contents directly related to their physical location are the key points of its learning and educational capabilities in the fields of architecture, urban planning and territorial management, and are characterized by their visual impact and their direct relationship to physical space.

Our hope is that the work performed in this research project may be used as starting point to develop new methodologies and technologies based on tabletop application as a supporting tool in order to enhance learning and knowledge generation in those fields and their environment linked domains.

The tool will also contribute to fulfill the mission of universities to provide knowledge not only to their on-campus students but also beyond the walls of the academy. New learning opportunities can be offered both to students and professional learners as well as to citizens in the wider community. Society in general could thereby receive more and expect more from universities in terms of what they deliver and produce. With the presented prototype, a real table has been realized, one that can contribute to overcoming the exclusivity of academic and bureaucratic professionalism.

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