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P. Rosenthal, R. S. Laramee, M. Kirby, and G. L. Kindlmann (Editors)

Using User-Centered Techniques for the Design and Evaluation of Interactive Visualizations to Support Urban and Regional Planning: Case Study Bogotá 21

D. Fernández Prieto[1] D. Zeckzer[2] and J.T. Hernández[1]

[1]Universidad de los Andes, Bogotá, Colombia
[2]Technische Universität Kaiserslautern, Germany

Abstract

User-centered techniques and evaluations are very important for the design of interactive visualizations. We applied the UCIV4 Planning Approach (User-Centered Interactive Visualizations for Planning) within the project "Bogotá 21". This approach proposes three activities that aim at gathering information about users and perform early evaluations as part of the end of each phase of the process. This paper presents the lessons learned from applying this user-centered approach to the "Bogotá 21" project and provides recommendations for improving future instantiations of this and approach and the included evaluations.

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [Information Interfaces and Presentation]: User Interfaces—User-centered design

1. Introduction

User-centered techniques and evaluations are very important for the design of interactive visualizations. The UCIV 4 Planning approach (User-Centered Interactive Visualizations for Planning) [FZH13] attempts to satisfy the need for more useful and usable visualizations as mentioned by several authors in the field of geovisualization [CMP04], [MK01]. To achieve this goal, user-centered techniques were introduced in the design and evaluation processes as they serve for example to engage stakeholders with the developed visualizations, to help finding 'undreamed requirements' [Rob01] associated to the displayed data, and to enhance the understanding of the problem domain. UCIV 4 planning proposes three activities that aim at gathering information about users and perform early evaluations at the end of each phase of the process. Studies such as Lloyd and Dykes [LD11] and Roth et al. [RRF*10] are representative in terms of highlighting the strengths and weaknesses of using certain user-centered methods in the context of geovisualization.

We applied the UCIV4 Planning Approach within the project "Bogotá 21" to support the analysis of the future development of Bogotá designing a set of interactive visualizations. "Bogotá 21: Towards a World-Class, Transit-Oriented Metropolis" is a project enclosed in the Cities 21 initiative developed by Siemens AG and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) whose purpose is to "highlight good practices to support the sustainable future development of megacities such as Jakarta or Bogotá" [Fed]. In the specific case of Bogotá 21, the purpose is to present a vision of the development of Bogotá and its surrounding municipalities in order to guide a sustainable and decentralized development in the region. Bogotá 21 was developed by Siemens AG and GIZ representatives in collaboration with the Urban and Regional Sustainability Research Group (SUR) and the IMAGINE Research Group from the Universidad de los Andes, Bogotá, Colombia.

This paper presents the results and the lessons learned from applying this user-centered approach to the "Bogotá 21" project and provides recommendations for improving future instantiations of this approach and the included evaluations.

2. UCIV 4 Planning Approach

UCIV 4 Planning is a user-centered approach for the design of interactive visualizations to support urban and regional planning processes [FZH13]. This approach consists of three

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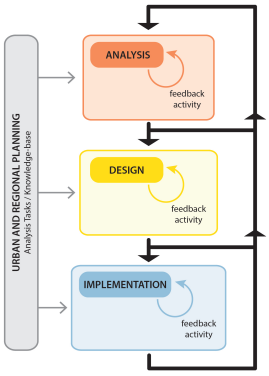

Figure 1: *UCIV 4 Planning Concept.*

phases: analysis, which is mostly based on the detailed description of stakeholders' analysis tasks; design, which focuses on the search for visualization and interaction guidelines related to the knowledge-base of the involved stakeholders; and implementation, which presents the resulting interactive visualization and the plan for its evaluation. Figure 1 illustrates the general concept of the applied approach.

Each phase includes two activities whose results are assessed by the stakeholders through a third activity (feedback activity, evaluation) that determines if it is necessary to repeat the phase or if you can continue with the next phase.

3. Case Study Bogotá 21

In the context of Bogotá 21, the purpose of using interactive visualizations is to ease the comprehension of the current state of the city and its surroundings as well as the impact of projected alternatives (2008 current state - 2050 future state). The work team was composed of: 2 software and computing engineers (master and doctoral level) who were in charge of the development of the interactive visualizations; 1 visualization designer who was in charge of guiding the visual design and the application of the UCIV 4 Planning approach; 3 land use and transportation experts who collaborated in gathering and selecting the data; one information visualization expert who was in charge of reviewing the visualization results before each feedback or evaluation activity; and 2 project managers from the domains of software and computing engineering, and urban planning.

Next, we are going to present the results of performing the activities for each of the phases proposed in the UCIV 4 Planning Approach.

3.1. PHASE 1: ANALYSIS

3.1.1. Activity One: Surveys and interviews

For this activity, 8 participants from 2 different domains (land use and transportation) were invited to participate in this survey and later in an interview. This activity lasted around 45 minutes and was conducted in the workplace of each participant. The first 5 minutes were used to fill out the survey that served to collect basic information about each stakeholder's expertise, their daily analysis tasks, and the data required to perform these tasks. For the next 40 minutes devoted to the interview, stakeholders were invited to answer the following questions:

- What do you need and want to know about the region of study?
- What kind of questions should be resolved during a planning process?
- What data sources provide these data?
- How do you solve the analysis tasks related to your domain? What are the steps?
- How could be improved the tools to facilitate the exploration and analysis of data?
- How interactive visualization could assist the development of your analysis tasks?

These open questions allowed us to explore possible *undreamed requirements* related to each stakeholder's perspective. At the end of this activity, we were able to: describe stakeholders' profiles, record the analysis tasks performed during a general planning process, and identify the required data needed to perform their analysis tasks.

3.1.2. Activity Two: Analysis task classification

Classifying the analysis tasks enables to infer visualization and interaction recommendations. The classification method introduced in the UCIV 4 Planning approach compiles and integrates the classifications proposed by Pinnel et al. [PDB99] for task types in the context of urban planning, Ogao and Kraak [OK02] for visualization operations, and Yi, Kang, and Stasko [YKS07] for interaction operations. Table 1 shows a classification example for one of the four analysis task identified in the Bogotá 21 project.

Task ID	001
Name	Densification capacity
Guiding question	What do we need to do to reach the recommended green open space for each locality type?
Description	Evaluate the ratio of green areas to buildings's height in 2008 and 2050
Associated data	• Average height of buildings • Location of green open areas • Population density • Current and recommended green open space index
Analysis task type	Quantitative information: Identify patterns of change for quantitative attributes of an urban element
Visual operations	Associate
Interaction operations	Explore, reconfigure, encode, filter and connect

Table 1: *Classification for the analysis task 001*

3.1.3. Feedback activity: Focus group

Once the analysis tasks were classified, we proceeded with the focus group session. The purpose of this session is to share with stakeholders the results of the two previous activities.

For this activity, 3 stakeholders were invited to participate in the session that lasted 60 minutes. First, a designated moderator gave an explanation of the classification criteria. Then, the suggested classification for each analysis task was presented to stakeholders and immediately a 10 minute discussion period was held with the purpose of verifying if the proposed classification was coherent with the original intention of the analysis task. As a result of this activity, an inventory of the analysis tasks was documented. The proposed classification for all four analysis tasks was accepted by the stakeholders.

3.2. PHASE 2: DESIGN

3.2.1. Activity One: Search of design guidelines

The purpose of this activity is to gather a set of guidelines directly provided by domain experts and international standards for urban and regional planning such as American Planning Association's standards [Ame]. We also attempted to strengthen these guidelines by introducing perception and cognition guidelines.

Three examples of the knowledge base, and perception and cognition guidelines used for the analysis task presented in Table 1 "Densification capacity" are:

- Developed sites (with buildings) are represented with "brown4" color (RGB:139,35,35) [Ame].
- Redundant mapping of data to multiple visual attributes helps the user to discriminate graphical objects in the scene [Bra99].
- Two approaches for displaying quantitative information on maps usually work best: variations in color intensity, in size, or both [Few09].

We found that clear guidelines are related to color use (particularly for land use classification) while conceptual guidelines are dispersed in the literature. In order to counteract this situation, the deliverable for this activity is a compilation of representation and conceptual guidelines found in the domain literature for each analysis task.

3.2.2. Activity Two: Prototyping

Different visualization prototypes were developed based on the complete set of guidelines. In this case, we used the Puente Aranda locality using the prototypes developed for the "Densification capacity" analysis task.

3.2.3. Feedback activity: Wizard of Oz

A Wizard of Oz test was planned to test the visualization prototypes and the interaction techniques. One of the most important aspects for stakeholders was the representation of changes over time. For this feature, we prepared a series of 10 images showing the transition of the buildings height data and green areas data for different points in time. Then, we put these images together in order to simulate an animation that stakeholders could "pause or resume" when desired.

For this test, 5 participants were invited to interact with the prepared animation. Since this test was designed to test only 2 features (changes over time and the application of guidelines), these sessions lasted 10 minutes. The results for this activity showed that being able to see the evolution of variables over time is essential for the comprehension of a behaviour or a trend.

It is important to note that this activity only included the test for a single interaction operation and this is a clear restriction for testing the whole functionality of the interactive visualization. From the visualization point of view, the produced prototypes looks very similar to the type of visualizations that can be produced with other commercial software. This represents an advantage and disadvantage at the same time. Certainly, the visualizations will be easy to read for stakeholders but a lack of creativity can also be introduced.

3.3. PHASE 3: IMPLEMENTATION

3.3.1. Activity 1: Identification of visual and interaction misunderstandings

Here, we present the conclusions of the previous activity in terms of the issues that can cause visual or interaction misunderstandings. The result for this activity is a list of suggestions and recommendations to be considered for the implementation of the interactive visualization.

For the prototype of the analysis task "Densification capacity", the changes that impacted the final interactive visualizations most were those related to color changes. It is important to evaluate whether it is worth making changes. If the suggestions and recommendations imply major modifications of the interactive visualization, a new prototyping cycle should be considered.

3.3.2. Activity 2: Selection of technology and development

We implemented the designed interactive visualizations using the "Visual Analytics Platform for Urban Systems" that is being developed by the IMAGINE Research Group at Universidad de los Andes, Bogotá, Colombia. The modular architecture of this system allows the implementation of diverse interaction techniques along with the implementation of diverse visual representations in a 3D environment taking into account time-related aspects. The results obtained are shown in Figure 2.

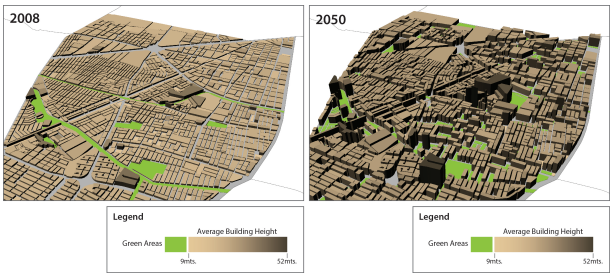

Figure 2: *Green Open Spaces vs. Average Height of Buildings for Puente Aranda Locality (perspective view).*

RQ1	Do participants easily recognize the orientation of the map at the starting point of the application?
RQ2	Can participants interact effectively with the interactive visualization?
RQ3	How easily and successfully do participants distinguish between the increase and the decrease of buildings' height during the animation?
RQ4	Can participants understand the relation between the height of buildings and the population density?
RQ5	Can participants complete their analysis tasks?
RQ6	What questions do participants ask as they work through their analysis tasks?
RQ7	Do participants find the interactive visualization more useful than other tools?
RQ8	How well does the interactive visualization support the goals and expectations of the participants?

Table 2: *Research questions for "Densification capacity" analysis task*

3.4. Feedback activity: Usability test

The usability test presented in the UCIV 4 Planning approach comprises the following usability criteria described by Tullis and Albert [TA08]: effectiveness, being able to complete a task; efficiency, the amount of effort required to complete the task; and satisfaction, the degree to which the user was happy with his or her experience while performing the task.

A task-based evaluation was designed with the purpose of answering the research questions presented in Table 2. Metrics such as task success, time-on-task, level of success, trials and errors, and learnability were registered during the test.

A room at the interactive visualization laboratory was adapted for performing the tests. After the implementation of 10 tests we noticed a deficiency in the tasks involving specific interaction operations. Even when the results of the usability test demonstrated the effectiveness of the interactive visualizations in terms of the visual encoding, there were evident shortcomings of the interaction techniques selected to explore, reconfigure, encode, filter and connect the displayed data.

We identified one possible reason why these shortcomings could occur. As the Wizard of Oz did not test enough interaction aspects, we may have omitted other key interaction operations in addition to possible composite interaction operations. These operations had to be evaluated previous to the final implementation of the interactive visualizations (specifically in the feedback activity of the Phase 2: Design). For this reason it is necessary to start a new design phase to strengthen the selection of the interaction techniques.

4. Lessons learned and conclusions

In the following, we present the lessons learned after the application of this user-centered approach for the design and evaluation of interactive visualizations to the case study Bogotá 21.

Unstructured interviews are helpful when trying to identify analysis tasks and undreamed requirements. Including open questions during the interview encourage stakeholders to talk about their experience in other projects. To keep the focus on the desired topics, it is recommended to have a checklist of the points that should be treated thus you can focus the conversation on these points.

After the execution of the feedback activity of Phase 2 we noted that a complete Wizard of Oz protocol is very hard to develop for a visualization system. The reason is that you must have modeled the visual response for all possible actions that a stakeholder will perform with the displayed data. Making rapid prototypes of interactive visualizations without investing too much time in programming is a great challenge. Alternatives such as paper prototypes integrated into a participatory design session can be introduced to this phase in order to overcome the difficulty of early assessments.

Designers should be aware of a possible pitfall when they follow strictly the knowledge-base guidelines. This can result in a lack of creativity because most of the stakeholders will always want to see familiar representations that they can easily interpret. In this respect, evaluating learnability aspects when testing different interactive visualization alternatives could give us an idea of the cost-benefit ratio in terms of the cognitive effort made and the findings obtained by the stakeholders.

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