ARspace: Augmented Reality and Visual Analytics for Improving and Monitoring the Quality of Public Space
Case: Las Nieves Neighborhood in Bogota, Colombia.

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Abstract— Public space is a prerequisite for sustainable living, and it should be planned with the citizens´ needs as a starting point. In this paper, the process to carry out a collaborative environment is explained in order to support the improvement of the quality of public space through direct participatory processes. After analyzing previous works, a different approach was explored: generation of data and information based on people's proposals and ideas and not on reports or complaints about the current state of public space. Augmented reality was chosen as a way for creating proposals and visual analytics in order to support collaboration and decision-making processes. Results showed a high level of acceptance by the stakeholders and, despite the difficulty in district institutions to work collaboratively and involve citizens, they acknowledged it is necessary to have comprehensive and inclusive visions to manage public space.

Keywords: Augmented Reality, Visual Analytics, Public Space, Participatory Urban Planning

1 Introduction

Public space is a prerequisite for sustainable living and "must play a central role in planning cities and urban areas" (Gehl, 2014). To achieve this, it is necessary that such work is done from the human dimension, that is, considering the needs and interests of citizens as they are the ones who use it and enjoy it (Gehl, 2014).

Colombia and in particular Bogotá recognize the importance of public space, defining it as crucial to consolidate a fairer society with more opportunities (Consejo Nacional de Política Económica y Social, 2012) and as "the structural articulator dimension for urban and territorial systems and public and private urban developments" (Alcaldía de Bogotá, 2005). At the same time, the difficulties are also acknowledged: there are shortcomings and deficiencies in the qualitative aspect (Consejo Nacional de Política Económica y Social, 2012), and "there is no proper use and enjoyment of public space, leading to a perception problem: This is everybody's and nobody's space" (Secretaría Distrital de Planeación, 2016). In addition, the

government defines the lack of tools to manage public space as a problem. For example, in the development plan draft of the current mayor of Bogota, it is stated that "the city does not currently have an information analysis tool for public space that facilitates the decision-making process to determine public investment" (Secretaría Distrital de Planeación, 2016). In this context, technology and information systems have a crucial role. This project involves two approaches:

1. Urban informatics (Foth, Choi, & Satchell, 2011): Based on this approach, we addressed two main roles: citizens and their empowerment through information and communication technologies (Unsworth, Forte, & Dilworth, 2014) (Hemmersam, Martin, Westvang, Aspen, & Morrison, 2016), and visual analytics support [16] to foster meaningful understanding and communication between citizens and decision makers [17] (Hemmersam, Martin, Westvang, Aspen, & Morrison, 2016).

2. Smart cities: One feature of smart cities is "the profound attention to the role of social and relational capital in urban development" (Caragliu, Del Bo, & Nijkamp, 2011). In a smart city, the community has learned to learn, adapt, and innovate, (Coe, Paquet, & Roy, 2001) and it is a city where the "people must be able to use technology in order to benefit from it" (Caragliu, Del Bo, & Nijkamp, 2011).

From this starting point, a question arises: What analysis model could support management and improvement of public space in a participatory manner, taking advantage of technology and information systems tools to facilitate these processes?

This project was called "Collaborative Environment to Support the Improvement and Monitor the Quality of Public Space in a Specific Area - Las Nieves Neighborhood Case in Bogotá". It was developed within the framework of the cooperation agreement between Universidad Jorge Tadeo Lozano and Universidad de Los Andes. Both institutions are located in the center of Bogota in Las Nieves neighborhood and, as leading academic institutions in this area, some of their responsibilities are the impact on the environment, their work with the community and the constant search for improvements in the quality of life in their area of influence.

The specific objectives of this project were:
• To identify and characterize stakeholders and their interests.
• To define an analysis model that explains the dynamics generated regarding the quality of public space and the stakeholders involved.
• To propose tools and methodologies that support the decision-making process related to the management and quality of public space and encourage participation and collaboration among the stakeholders

2 Related Work

Three projects were studied that focused on urban planning and the improvement of public space. They addressed this problem in different ways:

SeePlan (Hemmersam, Martin, Westvang, Aspen, & Morrison, 2016): It explores how to improve access to planning processes through information design and visualization. Using database records of the Planning Authority in Oslo, Norway, they created three tools: Planar, a mobile Augmented Reality (AR) application that provides access to information according to where the citizen is located. Planimator, a web application for visualizing data trends over time that shows the magnitude and speed of transformation of the city. And DynaPlan, a web application for visualizing the relationships between the different actors involved in urban planning.

Way2gether: This project uses AR in order to "make planned changes visible and reduce barriers caused by a lack of three-dimensional imaging" (Reinwald, Berger, Stoik, Platzer, & Damyanovic, 2014). The application has two sections: A two-dimensional map in which the user views his location and the points of interest (POI)

where the proposals made by state agencies are located, and the Augmented Reality viewer to display and navigate the three-dimensional models.

SeeClickFix: It is "a communication platform for citizens to report non-emergency issues, and for governments to track, manage, and reply--ultimately making communities better through transparency, collaboration, and cooperation" (seeClickFix, 2007).

The applications were reviewed keeping in mind the relevant criteria for this project: approach to the problem, data capture methodologies, stakeholders involved, technologies implemented, interaction and visualization techniques. Based on this analysis, four features that should be included in this project were defined: citizens and their devices as a source of information, feedback between stakeholders, tracking processes, and analysis tools to support decision-making.

However, in these three different studies, AR is used for visualizing information created by local authorities. This project proposes and explores a different use: AR as a tool for citizens to make proposals according to their interests and needs. In addition, this project aims to have a different approach: generating data and information based on people's proposals and ideas, not on reports or complaints about the current state of public space. The goal is to have sustainable urban planning projects in which participatory processes, community building, and improvement of public space according to the citizens' needs are strengthened.

Regarding visual analytics techniques, it is very important to reference the works related to visualization of space and time data. Andrienko et al., in their work "Space, Time and Visual Analytics" [16], emphasize that analyzing spatial data is no longer a unique task of professional analysts but that most citizens constantly perform it in their daily lives; therefore, it is necessary to create accessible and usable tools in order to facilitate their personal analysis. The different ways of measuring time -as a specific moment or as an interval-, the effects of spatial and temporal dependencies and the management of different scales to be able to analyze and make decisions, were fundamental issues that were considered in ARSpace.

In "VAUD: A Visual Analysis Approach for Exploring Spatio-Temporal Urban Data" [26], when talking about visual queries and visual reasoning, Chen et al, state that in the analysis of urban data, visualization is what often connects human intelligence with the data. This allows users to directly access the selected data and generate insights from what they observe without having to have prior knowledge.

Hughes et al in "GIS and Augmented Reality: State of the Art and Issues" [27], make a joint exploration of Geographic Information Systems (GIS) and Augmented Reality (AR). They show how the two technologies have converged. They define the 5 questions that a GIS must answer (where, what, how, when, and if) and generate a functional classification (augmented maps and augmented territories). Although the use given to AR in this project could be classified within the augmented territories because of virtual information that is visualized in real contexts, the difference is that our use of AR is not for visualizing data but for creating it, which would generate a new category within the classification proposed by the author.

3 Methodology

Based on the book Research Methodology [12], action-research was chosen as the research methodology because the project sought to understand the perspective of the participants about the phenomena that surround them, deepening in the way they perceive their reality and trying to improve the actions that are carried out [12]. In this specific case, the situation of public space was studied, focusing on improving the

citizen's actions that affect its quality, based on the problems of a specific environment (Las Nieves neighborhood) and with the full cooperation of the stakeholders from the beginning. The work was done under the prospect of a technical-scientific view that "consists of a set of spiral decisions, which are based on repeated cycles of analysis to conceptualize and redefine the problem again and again" (Hernández Sampieri, Fernández Collado, & Baptista Lucio, 2010).

The process had four stages: contextualization and stakeholders, definition of the analysis model, definition of the case study, and development of a prototype.

3.1 Contextualization and stakeholders

Three strategies were used to understand the context and to identify the stakeholders:

• Interview with expert: The project was supervised by Jose David Pinzón, an associate professor at Universidad Jorge Tadeo Lozano University (UJTL) and researcher at Corporación Universidades del Centro de Bogotá. He was the director of the specialization in Urban Design at UJTL in 2015 and is an expert in geographic information systems projects regarding urban and territorial analyses since 2000. Thanks to his experience and previous research work done in Las Nieves Neighborhood, the main problem was identified: conflicts among the different actors involved in the area (residents, merchants, floating population, public and private institutions). The main cause of these conflicts is that this area is in constant evolution, and it is difficult to create urban plans that benefit all the stakeholders.

• Workshops: Attendance to "Bogotá from the Center: City and University in the 21st Century" workshop (UJTL, 2015). There were representatives of public, private, and social stakeholders. The topic covered the problems and needs that each community has. They concluded that in order to find solutions, they needed to improve the lack of communication between them and make joint efforts to generate a real community.

• Study of district plans for the area: Two documents were analyzed: a) Plan de Ordenamiento Territorial (POT) which regulates the land use in Bogotá, establishes long-term strategies, and defines guidelines that apply to the entire city (Alcaldía de Bogotá, 2004); b) Plan Zonal del Centro, whose vision is to turn the city center into a "commercial, environmental, historical, cultural, tourist, residential, economic and administrative space that offers services with a high level of competitiveness, strategic leadership and is a cultural referent for the region" (Alcaldía de Bogotá, 2007).

Thanks to this fieldwork and data collection, it was concluded that this area has been characterized by its dynamic change and ambitious long-term goals for over half a century. Unfortunately, today there is no dialogue between the various stakeholders to facilitate these processes. Therefore, it is of fundamental importance to enhance communication and interaction channels between the stakeholders, in order to improve participation, planning, and to facilitate decision-making to make the vision a reality.

3.2 Definition of the Analysis Model

Two approaches were considered in the creation of the analysis model in order to find a solution to the problem:

• Spatio-Temporal Visual Analytics (Andrienko, et al., 2010): We are all spatio-temporal analysts. This type of task is not specific to skilled specialists as all stakeholders also use it in the development of their communities and regions. In order

to achieve this, appropriate tools that empower and involve them are needed. It is also important to note that "Spatio-temporal phenomena and processes exist and operate at different spatial and temporal extents […] The scale of spatial analysis is reflected on the size of the units in which phenomena are measured and the size of the units in which the measurements are aggregated" (Andrienko, et al., 2010).

• Participatory Urban Planning: To achieve sustainable and successful urban planning, it is necessary to have the stakeholders' participation and understand modern cities as systems that are constantly changing, linking many scales and containing many dimensions (Kunze, Gebhardt, Burkhard, & Tuncer, 2012).

Based on these approaches, a model composed of the following variables was proposed: a collaborative environment (how) in which time (when), space (where) and data (what) are aggregated to define different scales, in order to enable participation and analysis tasks by stakeholders (who) to solve problems and achieve better urban planning in the area where they are all involved (why).

Stakeholders were classified into three groups according to their main (but not exclusive) interests and functions. And these three groups were related to different scales of time and space (Alcaldía de Bogotá, 2004).

Table 1. Classification of Stakeholders

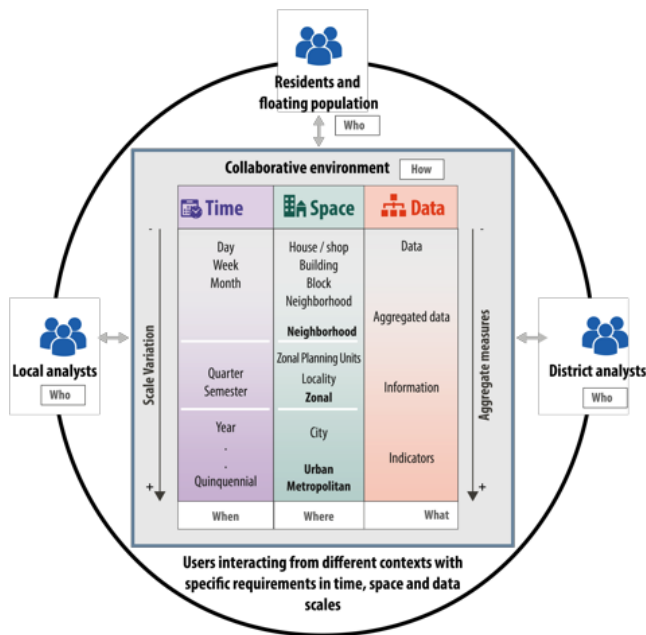| Group	Time Scale	Space scale
Residents and floating population	Daily to monthly events	Neighborhood scale
Local analysts (Public or private)	Monthly to semi-annual events	Neighborhood to zonal scale
District analysts (Public or private)	From semi-annual on	Urban to metropolitan scale

Fig. 1 - Collaborative Environment Analysis Mode

3.3 Definition of the Case Study

After studying the 'Plan Zonal del Centro' (Zonal Plan of the Center of Bogota) and conducting interviews among residents, it was concluded that two of the main needs were to improve public space and prevent its further deterioration.

To provide a theoretical base, two authors were referenced: Jan Gehl, Danish architect and urban design consultant, who states that: a) public space is a prerequisite for sustainable living and b) the primary task when building urban plans is to place the needs of the population, those who use and live in the cities, ahead of everything. [1]. And Wilson & Killing with their Broken Windows theory: "If a window in a building is broken and is left unrepaired, all the rest of the windows will soon be broken" [18]. "Physical and social incivilities generate fear in residents and workers of a neighborhood. Fear makes many stable families leave the area and the remaining residents isolate themselves and avoid others. This leads to increased anonymity and decreased social control. And the lack of control and increased disorder attract more potential offenders to the area, and this increases criminal behavior" [19].

Thus, we defined the quality of public space as the focus of the collaborative environment for the following reasons: it is one of the main axes of the "Zonal plan of the Center of Bogota"; it is one of the main problems in Las Nieves neighborhood; and it is considered a crucial factor to improve the quality of urban life.

The first approach taken was to create a tool that would allow citizens to report any deterioration of public space in different categories. However, after receiving feedback from a representative of each stakeholder group, new features were defined:

• It must be based on proposals and not on complaints: The district analyst explained that the district of Bogota would not be able to respond to all reports. If it were done through proposals, it would lead to more sustainable solutions.

• The appropriate institutions of each category must be part of the collaborative environment: The local analyst explained that these processes involve many institutions and it would greatly help if the cases could be directed to each of the appropriate institutions.

• Feedback processes between the different stakeholders are needed: The residents recognized that the best answer would be solving the problem in an immediate and tangible way. Meanwhile, it is important for people to feel they are being heard and that their actions were an invaluable contribution.

3.4   Development of the Prototype

The collaborative environment consists of two main sections:

3.4.1 Data Capture - Creation of Proposals

Through a mobile application, citizens can create proposals to improve the public space they frequent. Moreover, these proposals can be supported by votes from other people.

When thinking about the idea of transforming a complaint or report into a proposal, placemaking was considered. Placemaking is a process that seeks to inspire people to reimagine and collectively reinvent its public spaces and understand the needs and aspirations of people and communities regarding the particular place where they live, work, and play [20]. This methodology includes some qualities of an ideal place; out of these, seven were selected: safe, clean, green and bright places that are easy to access, help socialize and develop activities.

It became necessary for the project to find a way for citizens to create proposals, taking advantage of the devices they use daily. Augmented Reality was selected because it is a technology that allows to create reality-based interfaces where the real

world is complemented with virtual computer-generated objects that "appear to coexist in the same space as the real world" [21]. This allows citizens to see the results of their proposals immediately.
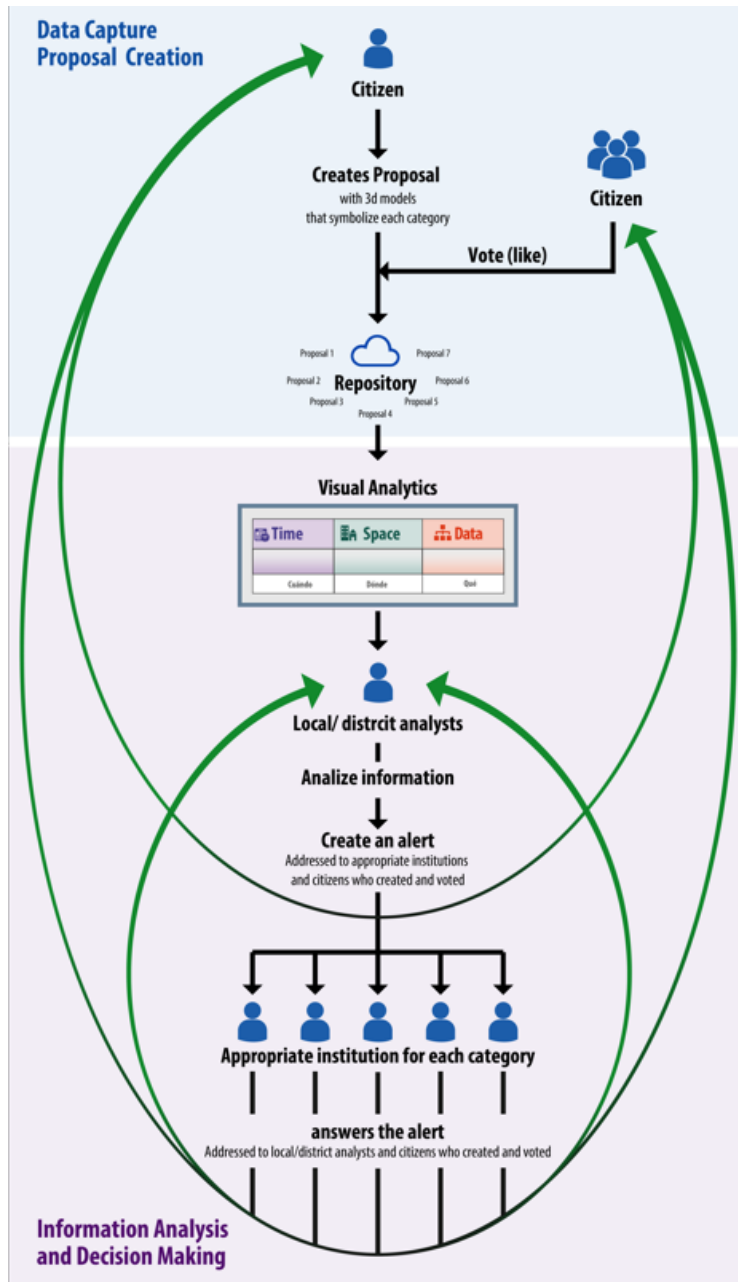

Fig. 2 - Collaborative Environment Structure

For the development of a fully functional prototype for user testing, a framework that allowed to publish on multiple mobile platforms and direct manipulation of three-dimensional objects was needed. Unity, a videogame engine widely used for virtual and AR content creation, was chosen, and SLAM (simultaneous localization and mapping) algorithms were used in order to obtain a good sense of reality in the integration of virtual objects. The citizen could see the image through his mobile phone, especially the alignment of the 3D models with the real ground.

3.4.2 Information Analysis and Decision-Making.

The stakeholders are the local and district analysts and the people designated by the appropriate institutions as partners within the collaborative environment. Analysts make a diagnosis of the area, detect opportunities for interventions or improvements in different categories, and generate alerts that are sent to the appropriate institutions based on the information collected through the proposals that were created and supported by citizens with the visual analytics web application.

Within the reporting environment, feedback among the various stakeholders is a fundamental element. For this reason, every action that is generated (sending alerts and responses) also reaches the community associated with the proposals (creator and supporters).

For the creation of the interactive visualizations that are part of the collaborative environment, we relied on the search mantra of visual information defined by B. Shneiderman [23]: "Overview first, zoom and filter, then details on demand": This means that, at the beginning, the user gives a general look at the interface in order to understand what is being shown to him and how it works. Then, he focuses on the section that called his attention. He refines his search with the available filters, and finally, he looks at the details of the information to verify if it was what he was looking for.

Fig. 3 – Collaborative Environment Interfaces: 1. Mobile Augmented Reality application, 2. General Status of the Zone, 3. Block Status, 4. Generated Alerts

According to this mantra, three sections were proposed:

• General status of the zone: Interface created to display the geographical location of the proposals. They are discriminated by category and they can be filtered by the number of votes, by a range of creation date or by its status (if it has been dealt with by the appropriate institution). Details of every proposal are also available to the analyst.

• Block status: This level refers to the number of proposals in a block and enables to define a status for each one (average of all categories or discriminated by each one) within a date range determined by the analyst. This average can be weighed. In addition, the analyst can see the evolution of each block over time, compare them and create an alert that is sent to the citizen and the responsible user of each category

• Generated alerts: It is a monitoring and control board. Alerts created by users are displayed with their appropriate status and details.

The prototype front-end was developed with Html, Css, Javascript, with the following libraries: Angular.js, leaflet.js, d3.js, crossfilter.js and dc.js. The prototype back-end was developed with PostGreSQL and postGIS for the database and GeotabulaDB, node.js, express.js and socket.io for the server.

4 User Testing

Formative assessment methodologies [28] were used for user testing. Qualitative information was collected mainly because the objective at this stage was to be able to identify and diagnose problems, identify what worked well with the stakeholders and thus design a positive experience that really resolved a need efficiently. Based on the article Evaluation of Usability Methodologies in the Universal Design Process [23], we chose two methodologies with each group of participants: Questionnaires (in-depth group interviews to measure relevance and intention of use) and performance testing (focused on usability, tasks performance and insight discovery) [24].

About the user groups, non-probabilistic samples were defined [12] with inclusion criteria regarding the two main tasks performed within the collaborative environment: information analysis and data capture (creation of proposals) through Augmented Reality.

4.1 Data Capture Test (Creation of Proposals)

In-depth interview: It had two sections: the relationship of the participants with the public space and demo of each component of the collaborative environment. It was conducted with eleven students from the universities located in downtown Bogota at Las Nieves Neighborhood and its surroundings. They were people who frequently use public spaces, not only for mobility but also to have fun and socialize. Everyone had to use a smartphone.

Performance test: It was applied to five participants from the previous group and it had two stages:

• *Basic manipulation tasks in virtual environments:* Interaction techniques for object selection and manipulation have a high impact on the quality of the interface in virtual environments [26]. The participants were asked to do the four basic tasks proposed in this environment: creation, selection, rotation and object removal. Then, they were asked about their perception regarding the ease of use.

• *Creation of proposals:* Participants had to create a proposal with at least three objects and save it in the system.

4.2 Practices of Seeking out Social Contact and Activity

In-depth interview: It had 3 main topics: public space management, citizens and public space, and a demo of each component of the collaborative environment.

It was conducted with employees of the Departamento Administrativo y Defensoría del Espacio Público de Bogotá (Administrative Department and Advocacy of Public Space of Bogotá - DADEP). Seven people participated in the interview. They worked in the following areas: social coordination, sustainability, legal, property and public space management.

The assessment carried out with this group of people was essential since this department is the main district institution for issues related to public space. The selection of the various positions allowed an analysis from different perspectives and a holistic view of the collaborative environment from this sample of experts.

Performance test. It had two stages:
• Demo of data capture in order to explain its operation.
• Tour through each interface of the web application. Each tour had 3 stages:

First impression: Participants were inquired about the sections they identified and the function of each one, without interacting with the interface.

Interaction tasks: Participants were asked to do the relevant tasks in each section, such as select, zoom, change ranges, apply or remove filters, among others. Then, they were asked about their perception regarding the ease of use.

Analysis tasks: Two questions were asked to the participants. They had to use the system in order to solve the challenge. This test was timed, and the data was predesigned to simulate possible patterns.

This test was applied to five participants whose profiles were:
• Three professionals in the field of urban planning, with experience in management of public space and spatio-temporal information systems.
• Two professionals with experience in digital interactive systems, information design and usability.

5 Results

5.1 Data Capture (Creation of Proposals)

Although the analysts (DADEP employees) did not use the AR tool, they watched the demo video. All the participants considered this was a good and relevant tool. They said it generates added value because these proposals come from the community and it creates a stronger link between citizens and their public space. However, they said people should be informed that these 3D models do not necessarily refer to real objects in order to avoid false expectations. They emphasized the great value of practicing participatory urban planning, but they recognized that it is a process that involves making changes in workflows and mindsets of public employees, which is not an easy task.

College students had a very positive impression of the tool and most of them would be fully willing to use it. They assessed it as a new way of relating to local authorities, which is a positive aspect because they do not believe in the way the procedures are currently done. They also believe that this helps to build proposals in a participatory manner, and not as an imposition, which is how they feel is happening today. However, they said it is necessary to prove that the tool is effective and that their proposals are actually considered by the district authorities.

In the performance test, there were difficulties when some users tried to rotate the objects or when the ground reference was too close, and they tried to move big objects. However, when the participants were asked how easy the application was to use, one said it was very easy, two said it was easy and three said it is neither easy nor difficult to use. This may show that the tool could be adjusted to make it even easier to use.

5.2 Information Analysis

When the visual analytics tool was evaluated, the analyst group rated it as a good project for the following reasons:
• It makes it possible to observe and evaluate trends of citizens' wants and needs.
• It has very high applicability in different aspects of various institutions.
• It responds to the need for tools that enable a comprehensive view of the public space quality.
Nonetheless, they recognized three important facts:
• Currently, collaborative work between district institutions is far from ideal: there is competition between them, and information is not shared.
• They suggested that the collaborative environment, as it was presented, should be used at higher levels (by the Mayor or the District Department of Government), and smaller modules with specific categories should be implemented in the other institutions such as Instituto de Desarrollo Urbano (Institute for Urban Development), Departamento Administrativo de la Defensoría del Espacio Público (Administrative Department for the Advocacy of Public Space), Instituto Distrital de Recreación y Deportes (District Institute for Recreation and Sports), among others.
• The adaptation to different regulations of every responsible institution for each category is needed.
In the performance test, participants recognized the different sections and they were able to guess their function correctly. Participants considered all the interaction tasks easy or very easy. However, they suggested a redesign of some graphical interaction elements so that its use can be made easier.
Finally, during the analysis tasks, all users made the right steps to solve the questions and found the correct answer. However, the time spent by the two most experienced participants in spatiotemporal analysis was 30% to 50% lower than the time spent by others..

5.3 Alerts and Feedback

These interfaces are mainly informative. The interaction tasks are: change of the alert status, display the system status when the alert is generated, and respond to the alerts sent to the employee in charge of a category. All participants recognized the different sections, understood their function, and considered it easy to use. Despite its simplicity, all participants considered this mechanism an essential part of the collaborative environment because it allows interaction between the different stakeholders.

6 Conclusion

Considering the fact that the aim of this phase is to shape the design of the solution through an understanding of the context, the definition of stakeholders, the

identification of their needs and interests, and the creation and qualitative assessment of various prototypes, we can conclude that:

• The collaborative environment supports the process for creating joint visions. It makes it possible for all the stakeholders that are involved in the planning, management and improvement of public space to participate, and it deals with the different dimensions that are part of the problem. Although it sounds obvious that there must be an integration between district institutions, this is not happening at present and even less when we talk about the collection of data generated by citizens. As expressed by the participants, each institution implements its own strategies and the traditional ways of collecting data do not motivate people nowadays. When proposing solutions such as ARspace, tools are used for facilitating communication processes with the citizens and for generating a greater sense of ownership with the improvements made in the public space because solutions emerge from the citizens and not as something imposed by the authorities.

• The project takes advantage of technology and information systems to support participatory urban planning. This was reflected on the three products we created: Augmented Reality as a tool that allows citizens to propose and dialogue with district institutions, considering their interests and needs perspective as a starting point; visual analytics as a tool that facilitates decision-making based on comprehensive visions and collaborative work among stakeholders and district institutions; and tracking systems (such as the proposed alert system) that allows the monitoring and control of processes and supports feedback between stakeholders.

• It is very important to think about the public space from the human dimension, as proposed by the urbanist Jan Gehl; after all, the citizens are the ones who use it and spend time on it. When there is a channel for listening to the citizens, when there is feedback to actions performed and when everything starts with the proposals of citizens (created from their spatio-temporal scale), more accurate diagnoses can be made, and sustainable solutions are proposed. Citizens will be more committed to care for the integrity of public space because solutions are proposed by them. In addition, by making participatory urban planning, decisions are legitimized and have greater support from society.

• This collaborative environment has an obstacle: the difficulty for district institutions to work collaboratively and involve citizens. This difficulty is caused by various administrative, political and social reasons. Collaboration among district institutions and stakeholders is essential to promote the development of citizens.

• It is necessary to have inclusive and comprehensive visions for the management of public space and this can be achieved through technology and tools like those developed by this project.

7 Future work

7.1 Development of District Analysts

It is necessary to develop tools directed to district analysts, whose needs and interests have larger scales in time (semesters, years, etc.), space (urban and metropolitan) and data (aggregated data, indicators, etc.). Furthermore, according to the suggestions made in the user testing sessions, it is necessary to work with the district institutions responsible for every aspect related to the quality of public space so that this collaborative environment will meet the specifications, needs and workflows of each one of them. Having these two distinct aspects, it is necessary to implement versions for local analysts and an integrated version for district analysts.

7.2 Improvements in Augmented Reality

The next step is to develop the in-situ visualization system of proposals. Some tests have already been made and proposals are being geo-referenced when they are saved. However, there is another process that needs to be explored: in the current prototype, three-dimensional models are predefined. It is necessary for these models to be consistent with the specifications of district institutions. We also want to explore how to implement the creation of proposals in a freer way, just created by citizens, with no predefined objects.

7.3 Integrating Data from Other Sources

This is discussed in the context of the two main tasks of the collaborative environment:
• Data Capture: It has been proven that the session's participants considered Augmented Reality relevant and innovative. However, there are other sources of data that can be integrated into the system. To cite a few examples: social networks (used often by citizens) and the city security cameras (this is not a participatory method but through image processing it could be used to verify and measure the deterioration of public space).
• Information analysis and decision-making: The system would benefit from the integration of other sources of information such as open data from Bogota and the institutions responsible for each category..

7.3 Automated Analysis

When the collaborative environment uses actual data, it is necessary to create algorithms that: a) discover relationships between categories (in time, space and data) and b) measure the impact of interventions in real life. With this information, knowledge is created. This would allow to characterize interventions, know their impact level, and thus, take preventive actions or generate more efficient solutions.

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