Representation Types and Visualization Modalities in Co-Design Apps

Barbara E. A. Piga
Gabriele Stancato
Marco Boffi
Nicola Rainisio

Abstract

This paper's primary goal is to analyze representation types and visualization modalities of web-based and mobile applications for collaborative processes in urban planning. To this end, a comparative study of several case studies, based on literature review, analysis of EU projects' websites, academic/commercial websites, web-platforms, application Platforms as a Service (aPaaS), Software as a Service (SaaS) dealing with co-design for urban design and planning purposes, has been done. We analyzed 56 commercial and non-commercial apps active from 2010 to 2020 across different countries. Despite the increasing level of innovation and commercialization of Augmented/Virtual Reality solutions and immersive visualization devices in the last few years, the emerging framework of ICT solutions for participatory processes in the urban planning field is still characterized by bidimensional representations and non-immersive visualizations modalities.

Keywords
public participation, mobile app, web-platform, virtual reality, augmented reality.

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Introduction

Over the years, co-design actions within urban transformation projects progressively included digital technology tools [Steinbach et al. 2019]. Such online solutions are usually limited to a base for discussions rather than an active design tool for citizens [Mueller et al. 2018]. Currently, mobile apps in participatory processes are also not so common and mainly focus on data collection [Ertiö 2015; Guo et al. 2014]. Anyway, a wide range of digital representation tools (from 2D GIS to 3D digital twins) are available to show urban information accurately; these can interactively support the understanding of spatial features to laypeople in the urban planning field [Al-Kodmany 2002]. Virtual Reality (VR) and Augmented Reality (AR), for instance, are efficient tools to involve citizens and professionals in virtually experiencing and foreseeing the effect of a design project [Piga, Cacciamatta et al. 2021; Piga et al. 2017]. Actually, for reliably assessing the physical, perceptual, cognitive, and emotional effects of an urban transformation [Boffi, Rainisio 2017], the reliability of simulation is crucial [Sheppard 2005; Piga 2018]. This paper focuses on the representation (2D, 3D) and visualization (immersive, non-immersive) modalities applied in such tools to engage citizens.

Method

A systematic literature review using the PRISMA method [Moher et al. 2010] was conducted to investigate the state of the art of the apps' representation and visualization characteristics in the urban participatory planning field. The apps were analyzed and compared based on a matrix that identifies their different characteristics according to the following macro-categories: i) digital representation and ii) visualization (Fig. 1). The 'digital representation' category refers to how the current urban condition or design solution is depicted according to the following sub-taxonomy: a) 2D representations; b) 3D representations. The 'visualization' category indicates the way models are rendered, referring to the Milgram-Colquhoun continuum [Milgram, Colquhoun 1999]. Therefore, the visualization modes are articulated into two sub-taxonomies: a) immersive, further divided into Mixed Reality and Virtual Reality; b) non-immersive [Piga, Morello 2015].

Co-Design Apps Framework

The literature review allowed us to identify 56 apps implemented across 22 different countries, namely: Australia, Austria, Brazil, Belgium, Canada, Denmark, England, Estonia, Finland, France, Germany, Greece, Haiti, India, Italy, Mexico, Kenya, Nepal, The Netherlands, Singapore, Spain, USA. The analysis of the representation modalities highlights that 63% of the apps use two-dimensional representations, whereas 37% use three-dimensional representations (Fig. 2a) with different degrees of realism and interaction. In most cases, the apps offer exclusively one type of representation. The analysis highlights that two-dimensional representations are widely used when dealing with urban scale and are often connected to campaigns using questionnaires or to voluntary crowdsourcing contributions [Kanhere 2013]. Vector maps are a common form of 2D representation [Al-Kodmany 1999] providing the digital base maps of the current condition. Integrating these solutions into other tools, for instance, to represent design project proposals, is often possible [Douay 2014; Douay, Prévot 2015]. Three-dimensional representations are employed at the urban and building scale. Indeed, some of the apps dealing with 3D models offer the visualization of entire cities or

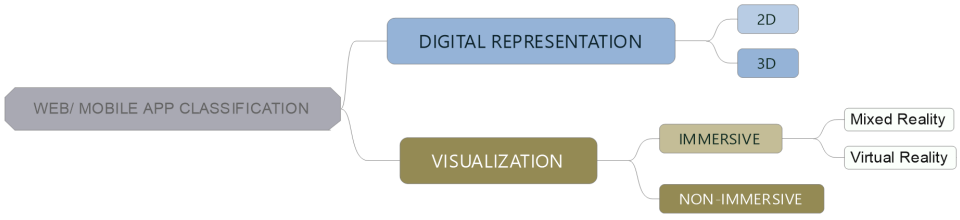

Fig. 1. Diagram of the classification modality adopted for investigating the apps.

neighborhoods, integrating information related to individual buildings, whereas others deal with architectural elements or even urban furniture, in some cases allowing the direct manipulation of the model itself. One app that adopts both representational modalities is City Sense, which uses the two-dimensional map as an orientation tool before allowing the users to interact with three-dimensional models in Augmented or Virtual Reality. Within the 3D model digital representation's subcategory, it is relevant to highlight a dichotomy: the use of 3D realistic virtual models versus abstract representation with a playful style. Despite their realistic or abstract representations, these three-dimensional models are used to display transformation projects (e.g., Virtual Singapore) or to allow final users to directly manipulate pre-established elements, or even to entirely modify the architectural model's components.
Concerning the visualization methods (Fig. 2b), 16% of the apps present the environment in an immersive way, whereas 84% use non-immersive modalities. Among immersive visualizations, Augmented Reality apps mainly show design projects in situ to verify their results at full scale and/or to record users' reactions; seldom they provide shared modeling tools in both location-based and markerless modes. Some apps of this type adopt Voxel models [Foley et al. 1996] as modeling and representational tools.

Apps Using 2D Maps

Carticipe (Debatomap in the English version) is an example of a web platform including a Public Participation Geographic Information System (PPGIS) method for collecting citizens' opinions and impressions. Users categorized their proposals in thematic headings provided by the app: i) mobility; ii) construction; iii) sports, culture, services, and commerce; iv) public spaces and green spaces; v) civic actions and the environment. Each category (Fig. 3a) is articulated in further subcategories described with a specific icon. Users can drag and drop these icons on the map to locate a proposal or a comment. Aggregated data is represented in bar-charts, heatmaps, or word clouds [1] by the app. The basic map is structured on Google Maps and allows users to switch the display between vector maps and satellite photos. A recent participatory process applying Carticipe is the "Concertation pour le Plan Local d'Urbanisme Intercommunal-Habitat", which started on July 1, 2021 and still ongoing, which involves citizens and project leaders to define the Local Housing Program (PLUi-H) considering the global warming issues and the agricultural land consumption.
Maptionnaire combines maps and questionnaires. It enables to spatialize proposals and to collect citizens' responses to specific requests. The customer defines which elements of the map the user can interact with by placing markers and drawing lines or polygons. Moreover, the system allows the customer to draw georeferenced elements; it is also possible to upload a raster image to be superimposed upon the standard map (MapBox, Bing, and Google Maps), georeferenced Geo TIFF files, or a shapefile. The questionnaire can include textual (e.g. multiple-choice, open question, semantic differential) or pictorial elements (e.g. images representing different project options). The platform also allows connecting maps with the major social networks. The system can aggregate data in heatmaps (Fig. 3b) or compare the drawings produced by the customer with feedback delivered by users on the map. An example of the application of Maptionnaire is the citizens' engagement process of the Helsinki's City Planning Department to define urban developments within a bottom-up process (2015)[2].

App Using 3D Models in Virtual Reality

Tygron (Fig. 4b) is a web app where users are involved in a game session with specific roles and budgets assigned; each role has a set of objectives to reach. The graphic style recalls the videogames graphics of the early 2000s. The user can interact with a three-dimensional model of a set of standard blocks categorized by function; in the current version, there are 17 categories (e.g. housing, agriculture, offices, parks, and medical facilities). Each category can contain various pre-set textured elements. The interactive model can switch between the current state and the design project. Environmental characteristics, such as heat or flood areas, can be represented as a color

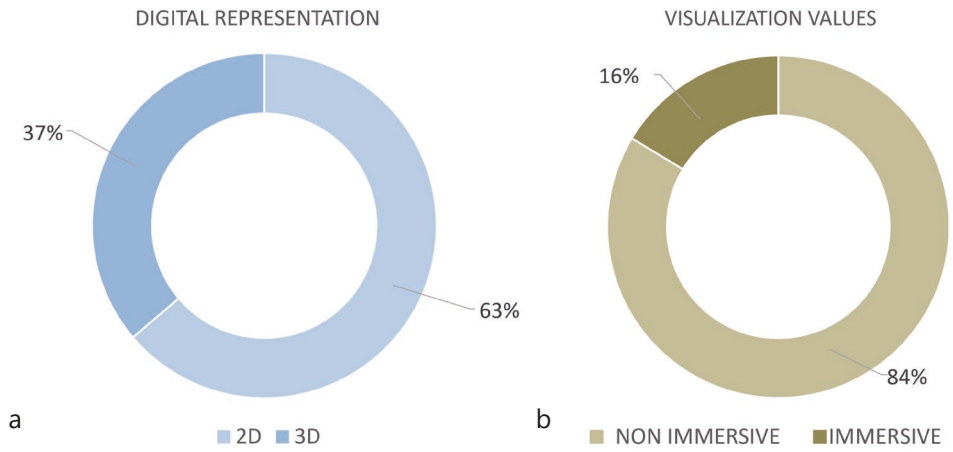

Fig. 2. a) distribution of the representation modes in the mobile and web app sample; b) distribution of the visualization modes in the mobile and web app sample.

gradient superimposed upon the model. Users' actions can influence other stakeholders' relevant objectives, and these interactions can induce shared decisions among participants. A remarkable application of Tygron was the participatory process organized by the Regional Energy Strategy North Holland South (Gooi, Vechtstreek, Netherlands) in 2019. The proposals for wind and solar plants installation[3] were shown in VR during an interactive session with stakeholders, civil servants, and council members.

The Kalasatama Digital Twins project, commissioned by the Finnish Ministry of the Environment, is an example of a multi-platform system allowing users to connect to the virtual model of the kalasatama neighbourhood (Helsinki, Finland) in multiple ways, for various purposes, and at different levels of user interaction [KIRA-digi 2019]. The Kalasatama model can display both the current state and the design projects under development in a logic of co-creation of the new city functions. In detail, the Kalasatama co-creation stages are implemented through the CityPlanner web app (Fig. 4a) developed by Agency9, [Ruohomäki et al. 2018]. Customers upload georeferenced three-dimensional models where users place their feedback using specific colors according to proposal categories (environment, residential, public works, health and safety, infrastructure, favorite place). The system can also integrate customizable questionnaires. CityPlanner itself has been developed through a co-creation process; the first application case was the "public participation GIS (PPGIS) poll" in 2015 to collect citizens' suggestions to improve tourism in Kalasatma [Charitonidou 2022; Hämäläinen 2021].

App Using 3D Models in Augmented Reality

Urban CoBuilder (Fig. 5a), developed by the Department of Architecture and Civil Engineering at Chalmers University of Technology, is a mobile app allowing a co-creation process where users can view and manipulate different design project options in AR [Imottesjo et al. 2020]. The app allows positioning standard-sized virtual blocks while viewing the project site in AR. The blocks are characterized by textures that differ according to their functions, e.g., offices, residential buildings, businesses, and green areas. Multiple users can interact with the same model, modifying the elements already positioned and adding new components. Users can have different roles (municipality, private, developer), and each role involves control over a specific budget. A cost is assigned in advance to each function, and when users locate the blocks, they view the budget used in real-time. Urban coBuilder is at a prototype development stage, a first step in testing the functionalities of the app involved architecture students in 2018; in 2022, two workshops focused on two ongoing campus development projects in Gothenburg, Sweden, by the Akademiska Hus (Gothenburg, Sweden) were done using the app [Imottesjo, Kain 2022].

Hyperform (Fig. 5b) represents an AR solution for designers and Real Estate developers' collaboration on architectural and urban projects. Created by Squant/Opera in collaboration with Bjarke Ingels Group (BIG) and UNStudio, it provides a shared immersive experience to designers and the other actors involved in the design process. The system allows uploading and displaying

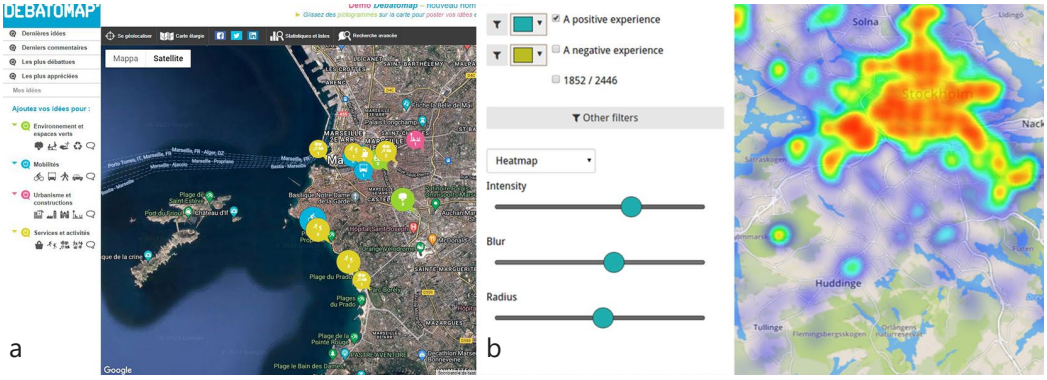

Fig. 3. Carticipe a) activities pins by users; source: Debatomap (2022). https://debatomap.reperageurbain.com/ (1 March 2022); Maptionnaire; b) heatmap of users' feedback ; source: Maptionnaire (2022). https://maptionnaire.com (1 March 2022).

images, maps, data, and 3D models and manipulating these collaboratively. The app also allows displaying projects at a 1:1 scale in AR on-site to clients and stakeholders of local communities, overcoming the typical characteristic of the predetermined perspective of renderings and videos. Hand-gestures commands are used for activating a pre-established set of actions. The Hyperform app is currently used in the research and development field of BIG and UNStudio, and is not available for public use.

City Sense (Fig. 6) is an AR/VR app using experiential simulation [Piga 2017], i.e. a simulation that allows photorealistic visualizations from a subjective perspective. It can be applied on several scales, from the building to the city scale. It represents the outcome of two Horizon 2020 EIT European Project "AR4CUP: Augmented Reality for Collaborative Urban Planning" (2019 and 2020). It collects and analyzes citizens' emotional and cognitive reactions to existing urban areas or design projects before construction [Piga, Stancato, et al. 2021]. The app is based on a combined architectural and psychological approaches, the exp-EIA© (experiential-Environmental Impact Assessment) method [Piga, Boffi, et al. 2021]. By clicking on a specific area or transformation project the user enter in a subjective view mode for virtually walk through the area in VR or AR. Some questions are asked to users during the walk. The app automatically processes the collected data and produces spatialized representations of the outcomes. City Sense has been applied in different public participation processes. The first application was made in 2019 during the "Experiencing VITAE" event presenting the preliminary project 'VITAE' by Covivio, Carlo Ratti Associati and partners, winner of the

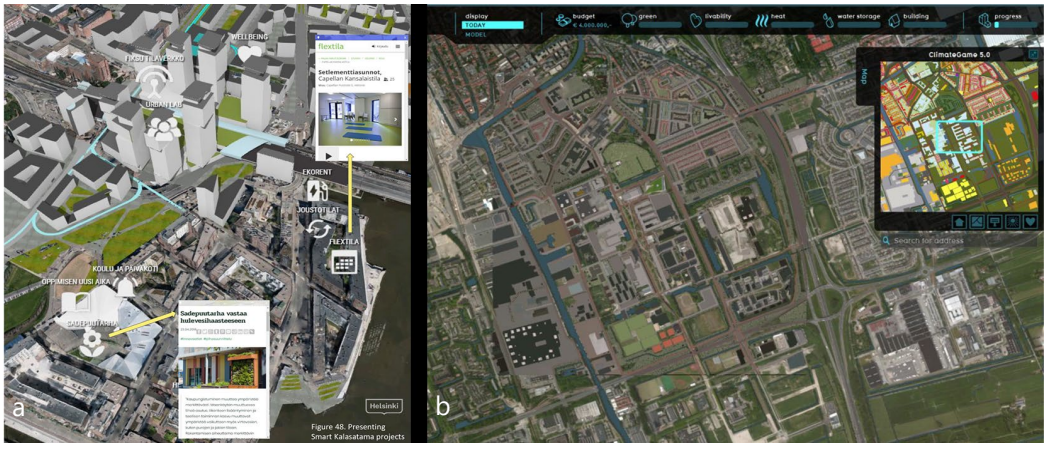

Fig. 4. CityPlanner Kalasatama a) informations on 3D model, source: [KIRA-digi, 2019]. Tygron b) main interface, source: [Koster, 2015].

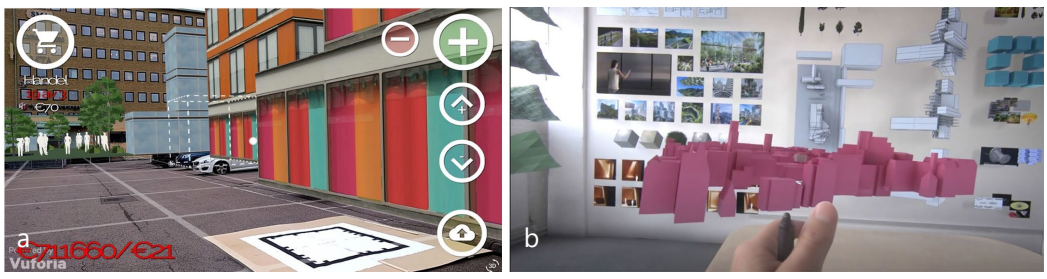

Fig. 5. Urban Cobuilder a) 3D blocks positioning in AR. Source: [Imottesjo, Kain, 2018]. Hyperform b) markerless interaction in AR, source: (Squint/Opera, 2019).

international competition Reinventing Cities (Via Serio) in Milan. Participants visualized the project on-site in AR, and their feedback, collected via City Sense and automatically analyzed, was presented to both the developer and the architects to inform the following design phases.

Discussion and Conclusions

The sample's analysis reveals that a sizeable segment of the apps in participatory urban planning uses two-dimensional representations (Fig. 2a). Textual descriptions are also widely used as a primary communication mode. These features are often intertwined by solutions allowing geo-located text; in particular, maps are often augmented with users' comments and judgments. Furthermore, some apps use geo-localized questionnaires to correlate location and responses accurately. Compared to other literature reviews on participatory apps, primarily oriented toward describing the political-administrative characteristics related to the tools [Falco, Kleinhans 2019], this paper focuses on representation and visualization features as an engagement tool for urban collaborative processes. However, whereas Virtual Reality has been experimented in co-design since the nineties [Al-Kodmany 2002; Evans-Cowley 2011], Augmented Reality has been applied more recently in participatory processes, and consequently, there is less literature on the subject [Ertiö 2015; Hanzl 2007; Thiel, Lehner 2015]. The increasing pervasiveness of high computational performance of mobile devices with immersive interaction modes suggests that an increase of Augmented Reality apps for participatory processes in urban planning will occur in the next, and maybe near, future. Although several applications are currently available for collaborative design at different spatial scales, what is not fully developed today is a single inter-scalar solution that covers all design phases at different levels of complexity. An app, recently developed and still in evolution, aiming to provide this comprehensive support is City Sense, which makes use of AR, VR, immersive and non-immersive modalities to engage citizens in multiple conditions, i.e. allowing *in-situ*, blended, or remote online interactions.

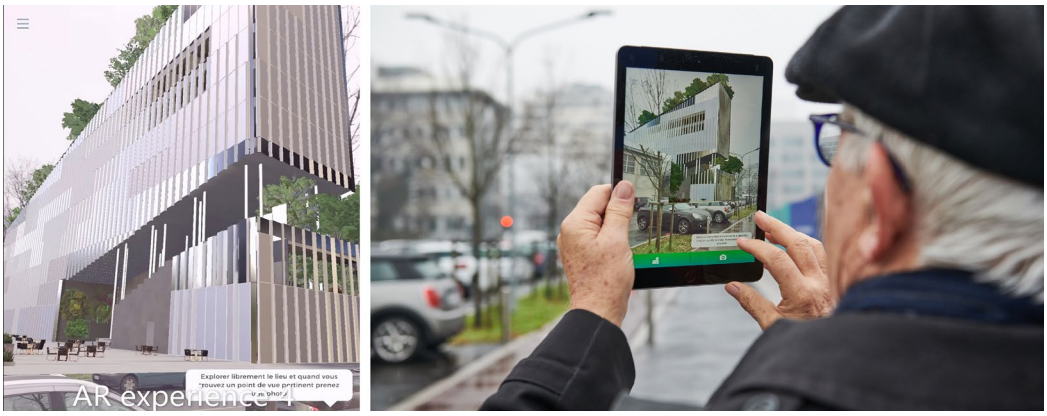

Fig. 6. City Sense: the display of the architectural model in AR mode (right); observation of the model in situ via tablet. The images were taken during "Experiencing VITAE", event held on 16/12/2019.

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Notes

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Authors
Barbara E. A. Piga, Dept. of Architecture and Urban Studies, Politecnico di Milano, barbara.piga@polimi.it
Gabriele Stancato, Dept. of Architecture and Urban Studies, Politecnico di Milano, gabriele.stancato@polimi.it
Marco Boffi, Dept. of Cultural Heritage and Environment, Università degli Studi di Milano, marco.boffi@unimi.it
Nicola Rainisio, Dept. of Cultural Heritage and Environment, Università degli Studi di Milano, nicola.rainisio@unimi.it

 Isbn 9788835141945