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In search of visualization challenges: The development and implementation of visualization tools for supporting dialogue in urban planning processes

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Abstract

Today, urban planning processes involve many stakeholders and efficient dialogue tools are needed to support communication in transdisciplinary environments. The aim of our study is to identify visualization challenges in urban planning. Based on a state of the art study and a thematic analysis of 114 articles, published in 2004–2014 and found through snowball sampling, the development and implementation of digital visualization tools for dialogue are discussed. A wide range of examples of visualization tools for dialogue has been found; either based on 2D maps, 3D environments or gaming. The initiators of the development originate from different disciplines, such as geographic information (GI) science, computer graphics, 3D modelling, Virtual Reality, interaction design and urban planning. There has been an increasing amount of usability studies during recent years. There is a tendency for the usability studies to have gone from experimental and prototype studies to more and more concern real planning processes and implementation. Studies of implemented tools in real planning processes are, however, still rare. Gaming appears more and more frequently. Challenges are related to integration of qualitative and quantitative data, representation of data as regard appropriate levels of realism and detailing, as well as the user's experience and the appearance of the digital models. There is a need to consider how we can achieve the full potential of visualization tools, including optimal effectiveness of visualization tools and processes for dialogue as well as how they can be implemented. Organizational preparedness is necessary, including clear ownership, allocation of resources for maintenance, competence and access to tools and technology.

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Introduction

In today's society, there is an increased need for continuous citizen dialogue on urban development, starting early on in the planning process. The implementation gap between vision and action in urban planning prevents the development of sustainable cities and reveals the need for more involved citizens and stakeholders who contribute to mutually agreed upon solutions (Abelson et al., 2003; Statens offentliga utredningar (SOU), 2012). With broader knowledge production and participation the conditions for consensus improve, which in turn may decrease the risk of conflicts of interest.

The level of participation in urban planning processes differs depending on the level at which cities are prepared to involve stakeholders and in what way. Technological developments, which among other things offer a number of visualization tools, are considered both an opportunity and a challenge for participatory urban planning (Kahila and Kyttä, 2010; Kanervo, 2010). Based on Arnstein's ladder of empowerment from 1969 (Arnstein, 1969), several models of e-planning have evolved for explaining levels of participation in relation to communication tools (Carver et al., 2001; Hanzl, 2007; Hudson-Smith et al., 2002; Kingston, 2002). According to these e-planning models, visualization tools with a high degree of interactivity ought to be important in creating opportunities for good communication that, in turn, can create higher participation in dialogue processes. Senbel and Church (2011) developed six instances of design empowerment based on the work of Arnstein as well as Rocha (1997) and showed that the potential for strong levels of empowerment is larger than the documented reality. For the higher levels of empowerment, 3D models had the greatest potential. A collective great potential was shown when several methods were combined (Senbel and Church, 2011). In a recent article, Brown and Kyttä (2014) state key issues and research priorities for Public Participatory Geographical Information Systems (PPGIS) based on around 40 of their own empirical studies.

Already a decade ago, the need for appropriate tools for communication at different stages of the design process was pointed out, as was the need for tools that support real world projects by the integration of virtual environments (Al-Kodmany, 1999, 2002; Plaisant, 2004). Since then, visualization has been integrated into tools for dialogue with the purpose of involving citizens and stakeholders more deeply in urban development processes. Still, there is a need for improvement in planning for the public and with the public (Brown and Kyttä, 2014; Klosterman, 2012), and the importance of evaluating implementation has been acknowledged (Morckel, 2010; te Brömmelstroet, 2013). This leads us to the overarching interest of our study: Where are we heading and what are the challenges we will face on the road?

There is an ongoing development of visualization tools both within and outside academia, and in a variety of disciplines. Most of the visualization tools developed outside research are not described in scientific journals, but the discussion is being pursued in other media, such as on the Internet (in blogs; company websites; and various forums, such as YouTube and Facebook), and branch journals. Thus, the communication culture in these kinds of media differs from that found in the scientific community.

The authors of this paper, with a background in architectural research, have a research focus on visualization within sustainable urban development. Our research deals with visual representation of the built environment; visualization of scenarios in transformation projects; and modelling of building stocks and environmental data. We have an extensive experience of working in practice based demonstration projects (Stahre Wästberg and Billger, 2015; Stahre et al., 2008; Stahre Wästberg et al., 2013); living labs (Billger et al., 2012; Habermann et al., 2015; Karlsson et al., 2013; Lindholm et al., 2014); GIS and modelling of building stocks (Thuvander, 2002; Thuvander and Tornberg, 2005), where visualization as a dialogue tool has been an important factor. Our research has primarily been carried out in transdisciplinary environments with cooperation partners ranging from university, municipality, and actors in the construction sector such as architects, property managers and technical consultants. Tool development, often in early phases, usually has played a central part, together with practical implementation of tools. The projects have been closely connected to real life scenarios, however not always put into production. Besides our stated research agenda in each project, we have come across issues connected to implementation; maintenance of the developed tools; further development; and future ownership.

Aim

The aim of this study is to identify visualization challenges in urban planning, and to discuss the development and implementation of digital visualization tools to support dialogue. In order to define these challenges, we ask the following guiding questions:

- What kind of digital visualization tools for dialogue in urban planning processes can be found in the research literature?
- Who develops for whom?
- How is usability evaluated in tool development processes?
- Which problems are stated concerning data handling and representation?
- Which problems with development and implementation of digital visualization tools are pointed out in the articles?

Scope and definitions

In this article our analysis focuses primarily on the research literature, rather than other sources. Within urban planning, different types of tools for dialogue processes are used (planning support systems; participatory planning systems; spatial decision support systems; and public participation geographic information systems). Here we refer to them collectively as ‘visualization tools for urban planning’, and the attention is on all kinds of dialogue tools containing a visualization component. Our focus is on visualization tools applicable for dialogue with different purposes in the context of urban neighbourhoods and cities. There is an increasing interest in applying visualization tools in regional participation, however, in order to get an amount of manageable material, studies lacking an urban focus have been generally disregarded.

The term *Dialogue tools* is referring to tools supporting a two-way communication process, and they can be both analogue, such as board games, role plays, paper based maps, and post-it stickers; and digital, such as web portals, digital games and interactive maps and city models. Our focus is on digital tools.

By *visualization tools for dialogue* we refer to tools that support dialogue through visualization. They are here regarded as systems based on a 3D city model or a 2D city map used in participation processes within urban planning and involving different levels of interactivity and/or presentation techniques. Examples of functions within visualization tools for dialogue are gathering and sharing location based information; collecting experience based data; and enable discussions about a place. The purpose of these kinds of visualization tools is to give citizens the opportunity to present their feedback as well as offer their ideas for sustainable urban development.

The term *visualization* is used in a broad sense and comprises digital tools and approaches that are based on, for example, 2D/3D visualizations and different forms of geovisualization, i.e. georeferenced spatial data, and information visualization, that are implemented in Virtual Reality (VR) and Augmented Reality (AR) environments.

Virtual Environments are considered to be spatial environments in a computer generated 3D world. The term 'VR' is used to refer to the technology, while the term 'virtual environment' refers to the digital spatial environment.

Method

The present research is a state of the art study that explores the development and implementation of spatial visualization tools supporting dialogue in urban planning processes. Developments in the field are progressing fast and a vast number of publications are available from different sources, generating many references being found with a broad search, but only a few that are within the scope of our study. Therefore, we apply the so called "snowball effect" for finding relevant articles. By snowballing we refer to a process in which you start with a small number of articles and expand this number with the help of the initial ones. In the process of reading these articles, attention is payed to the articles cited in these, as well as those articles in the reference list that we deemed relevant, which we then started reading and evaluating (Ang, 2014). For the searches, we have not only focused on articles published between 2004 and 2014 in scientific journals, conference proceedings, and reports, but also on books and ongoing activities in practice as presented on websites. These have dealt with research on visualization platforms; gaming as dialogue tools; visual representation in architectural and urban planning; and the use of virtual environments in urban planning.

In our survey of the articles and reference lists, the most important search words used in different kinds of combinations included: "decision support systems", "dialogue process", "dialogue tool", "gaming", "GIS", "participatory design", "PPGIS", "PSS", "public participation", "urban planning", "visualization" and "visualization tool".

Firstly, we searched among the key references as well as the key authors within our own research areas, and looked for their latest research concerning these issues. As a snowball effect of evaluating these references we found new ones, starting with a few authors' names or a few article references from our research area.

Secondly, we reviewed articles published in two scientific journals, namely *Environment and Planning B: Planning and Design* and *Computers, Environment and Urban Systems*. By examining relevant articles suggestions of other articles have been found through their lists of references and included in our study. Altogether the searches resulted in total of 114 publications, i.e. the empirical material and text corpus, for further analysis.

In the next step, the content of each article was reviewed and coded using a framework for analysis, i.e. a matrix, to compile the main features of each article and to identify patterns. In order to answer our guiding questions, the matrix was designed to contain the following aspects for coding: Application of the tool; type of visualization; keywords of the article, affiliation of authors; types of collaborations in tool development; type of data; level of abstraction; scale and perspective; evaluation of the tool; stage of tool development; and identified problems pointed out in the articles. There was also a column for our comments regarding relevance and quality of the article.[1] For each article, the coded parts of the text were copied and stored in the matrix.

Using the matrix as base material we not only answered the research questions, but also identified problem areas which later came to be translated into challenges. For that, the method which we used is inspired by a so-called thematic analysis (Braun and Clarke, 2006). An inductive, data driven, bottom up approach was applied when searching for challenges in the coded text within the matrix. This coded text was read and re-read several times and, if necessary, the original publication was re-read. The challenges emerged from topics appearing frequently and those are accounted for in the subsequent results sections. It should be emphasized that conducting the literature searches and analysis involves interpretation at many stages: Selection of the publications; grouping; selection of questions for text coding; creation of themes; and interpretation of the meaning and significance of results.

A mapping of the keywords from the studied articles illustrates the focus areas for the research. A compilation in a frequency map presents the most commonly occurring words, by that, shows the body of our study. The most frequently used keywords are: visualization, urban planning, virtual reality, public participation and planning (see Figure 1).

Figure 1. Visualization showing the frequency of the different keywords from the articles (Image created in WordItOut).

Results from the literature search: Answers to the five guiding questions

In recent years, a number of reviews related to visualization and urban planning processes have been published. Many have focused on technical matters, i.e. descriptions of technical developments in a certain field such as geocomputation, GI science and geovisualization (Cheng et al., 2012; Dykes et al., 2010; Goodchild, 2012; Plata-Rocha et al., 2011), certain aspects of virtual geographic environments (Lin et al., 2013; Rae, 2011) or geospatial cyber infrastructures and application domains (Yang et al., 2010). Other reviews have focused on visualization environments and techniques (Pettit et al., 2012a), the complexity of models for urban and regional planning (Klosterman, 2012), data/simulation models and their potentials for application in other contexts (Jerrett et al., 2005; Schwarz et al., 2010) or compilation of problems related to visualization (Lai et al., 2010). While early reviews discussed digital visualization and the user perspective in public participation planning (Hudson-Smith et al., 2002; Paar, 2006), later ones have focused on the user experience and presence (Gordon et al., 2011). Some have taken a closer look at the history of PGIS and guidance for future research and practice (Sieber, 2006), or implementation issues (Brown and Kyttä, 2014; Morckel, 2010; te Brömmelstroet, 2013). Only a few reviews have concentrated on usability studies and implementation (Bishop et al., 2013).

What kind of digital visualization tools for dialogue in urban planning processes can be found in the research literature?

Many of the research articles concern the development of new visualization tools for dialogue aimed at supporting sustainable city planning in terms of information sharing, analysis, development, presentation and communication of ideas throughout the planning process. These visualization tools are often systems integrating different functions on one platform (see Figure 2). Examples of visualization tools based on 2D maps are *Urban Mediator* (Saad-Sulonen and Botero, 2010); *ArgooMap* (Boroushaki and Malczewski, 2010); *Web Map Media; Shadew;* and *Tell a story* (Halttunen et al., 2010); *Community PlanIt* (Gupta et al., 2012; Reinart and Poplin, 2014); and *Urbania* (Cederbom, 2013). Tools using 3D visualizations are, for example, *VisuCity* (Ban et al., 2011); *Urban Strategy* (Pelzer and Geertman, 2013; te Brömmelstroet et al., 2013); *CSDILA* (Amirebrahimi and Rajabifard, 2012); *AURIN portal visualization toolkit* (Pettit et al., 2012b)*; Gothenburg City Model* (e.g. Sunesson et al., 2008); *My City*[2]; *Nanao City Model* (Shen and Kawakami, 2010); *CommunityPlanIt* (Gupta et al., 2012); and *My Blocks* (Brand and Kinash, 2013; Svensk Byggtjänst, 2013; Hultgren, 2011).

Typical functions for 2D platforms include gathering and sharing location based information. There are different kinds of functions on these platforms for collecting experience based data and enable discussions about a place. Examples of such functions are to place markers on a map, generate pictures, upload images, voice recordings and hyperlinks. It can also be possible for several people to sketch on, and modify the same document in real time (Boroushaki and Malczewski, 2010; Halttunen et al., 2010; Wallin et al., 2010).

Three-dimensional visualization tools primarily aim to show the physical environment in the city. In these tools the focus is on visual aspects and experiences of the environment. For example, to display and test different development scenarios of the built environment (Amirebrahimi and Rajabifard, 2012), or to visualize how new buildings and different alternatives design elements will affect the experience city, where dynamic scenes can then

Figure 2. Conceptual illustration of a visualization tool used in a dialogue process.

be created and experienced in VR environments (Shen and Kawakami, 2010; Sunesson et al., 2008).

Moreover, we can find development scenarios that visualize non visible aspects of the built environment based on procedures such as simulations (Pelzer and Geertman, 2013; te Brömmelstroet et al., 2013), or multi criteria evaluation for analysis of certain aspects of urban planning alternatives (Ban et al., 2011). An additional kind of city modelling involves using game engines and rule based programming (Watson et al., 2008). Gaming was recently introduced as a visualization tool in urban planning processes. Reinart and Poplin (2014) presented an overview of games available on the market and their potential for application in urban planning. Out of 24 games only two digital games (*Community PlanIt*[3] and *Minecraft*[4]) implemented criteria such as participation, interaction, realistic visualization, learning effect and knowledge transfer. *My Blocks*, based on *Minecraft*, has been developed into an interactive, user friendly 3D platform to create a common ground where different stakeholders visualize ideas, suggestions and future development of their living environments (Hultgren, 2011). By 2016, *My Blocks* will have been used by UN Habitat in 300 urban development projects all around the world (Brand and Kinash, 2013; Svensk Byggtjänst, 2013). Originally, *Minecraft* is a gaming platform, however, for city planning projects, mainly its user friendly, interactive 3D visualization function are used. A new process connected to game based learning is immersive planning involving aspects of challenge, sensing and imagination (Gordon et al., 2011).

There are several examples of geo based web portals directed towards citizen engagement. Community based geoportals add value by integrating social data and geographical dimensions (De Longueville, 2010). The *AURIN* portal[5] in cooperation with the *Center for Spatial Infrastructures and Land Administration (CSDILA)* provides datasets and open source visualization tools (Amirebrahimi and Rajabifard, 2012; Pettit et al., 2012b).

The SoftGIS portal,[6] based on an interactive map used for gathering information, has been used in several development projects (Brown and Kyttä, 2014). A further development of this tool is the newly launched web portal *Maptionnaire*, which is an online platform that allows you to create map based questionnaires for different types of cases.[7] *Community PlanIt*, an online mission based game that includes interactive maps, is also a portal used in different projects (Gupta et al., 2012).[8]

AR is considered having a great potential in urban planning, as it achieves a realistic representation in real time at the actual site of the proposed built environment (Ashraf Khan and Dong, 2011; Cirulis and Brigmanis, 2013; Hanzl, 2007).

Regarding the narrow field of multi sensors, one future development involves using several senses in addition to vision, i.e. sound, smell and the haptic senses (Jacob et al., 2012). All these above mentioned tools need different levels of expertise in order to be properly used. The tools range from those requiring expert knowledge, such as a specially trained technician, for usage and maintenance (e.g. *Urban Strategy*), over tools requiring expert knowledge from planners (e.g. *Urbania*) to non-expert tools (e.g. *ArgooMap* or *My City*).

Who develops for whom?

In order to understand the intention of the tools it is important to look into the perspective of the developer and for whom the tools are intended. The organizational affiliations of the researchers, i.e. their research environment, are commonly known through their publications. However the disciplinary backgrounds of the researchers are generally unknown. What is of interest here is if a researcher develops a tool for another researcher (often early in the development of the tool), if the researcher develops a tool for presumptive users and wants to test it, or if the aim is to implement a tool.

We have identified five different categories/types of collaborations in development of tools: (1) researchers developing for researchers; (2) researchers developing for hard or software developers; (3) researcher developing for decision makers/stakeholders within urban planning; (4) researchers developing for different groups in society; and (5) joint collaboration between researchers, software/hardware developers, and decision makers/ planners (see Table 1).

The most common scenario is when researchers develop tools for decision makers or stakeholders within urban planning, for example, city and regional planners, architects or traffic planners. In some projects, tools are developed as a close joint collaboration between researchers, software and hardware developers, and decision makers and planners. In other studies, the researchers' target groups are other researchers, software and hardware developers, or different groups in society, such as travellers, various emergency personnel, communities and the public. Common for this group of studies is that they do not address decision makers. Tools developed by practitioners are often not documented in scientific literature, thus they are difficult to grasp.

How is usability evaluated in tool development processes?

Usability studies concern evaluation of the tools' functions and the technologies' potential to improve participants' understanding and performance. Fundamental aspects of developing visualization tools for dialogue include studying the needs, requests and expectations of target users. When a visualization tool for dialogue or a system is being developed, tests are necessary in order to evaluate the tool's function and content.

Table 1. Categorization of collaborations within tool development.

Who develops for whom	Examples of articles
Researchers developing for researchers Researchers developing for software and hardware developers	Dawood and Sikka (2008); Drettakis et al. (2006); Döllner (2009); Heo et al. (2013); Horelli and Wallin (2010); Hultgren (2011); Jacob et al. (2012); Lorenz and Döllner (2010); Nebiker et al. (2010); Ostermann (2010); San José et al. (2011); te Brömmelstroet (2013); Svensk Byggtjänst (2013); Wang and Li (2010); Wu et al. (2010)
Researcher developing for decision maker/stakeholder urban planning	Aaltonen and Holmström (2010); Amirebrahimi and Rajabifard (2012); Boroushaki and Malczewski (2010); Döllner et al. (2005); Halttunen et al. (2010); Kahila and Kyttä (2010); Kjems (2004); Long et al. (2011); Pettit (2005); Pettit et al. (2006, 2012b); Poplin (2012); Rixon and Burn (2008); Roupé (2013); Saad-Sulonen and Botero (2010); Senbel and Church (2011); Shen and Kawakami (2010); Staffans et al. (2010); Stahre et al. (2008); Thaung et al. (2012); Wang et al. (2008); Wridt (2010); Zhang and Fung (2013)
Researchers developing for different groups in society (travellers, emergency personnel, communities, the public)	Ashraf Khan and Dong (2011); Poplin (2014); Roussou and Drettakis (2005)
Joint collaboration between researchers, software/ hardware developers, decision makers/ planners	Bailey et al. (2011); Ban et al. (2011); Bennett et al. (2012); Kyttä et al. (2013); van Lammeren et al. (2010)

We have identified a number of types of usability studies that have been carried out. A smaller proportion of the articles present what we call 'user needs analysis' for a group of professionals, where the use of, and needs for, digital planning tools are mapped out. In the material, two types of experimental studies can be found, the bulk of which concern studies in simulated settings. By this we are referring to studies in which different aspects of existing techniques are examined in a laboratory setting or a setting simulating a planning process. A few of the experimental user studies are carried out in real planning processes. The greatest proportion of the articles concern tests of prototypes of visualization tools for dialogue. These prototypes can be a specially designed tool or a set of existing tools combined to form a tool kit. Almost all of the prototype studies are carried out in simulated settings. Other usability studies focus on the process rather than the tool. They present the development and thorough examinations of the dialogue process supported by the tool. Such studies are carried out in simulated settings with relevant stakeholders in scenario workshops. Finally, there are a few studies that focus on implementation of visualization tools for dialogue and are carried out in real planning processes. They concern different stages of the implementation. A common trait for the investigated implementation studies is that they have been allowed to influence the planning process. Table 2 summarizes the different types of usability studies.

In experimental settings, usually factors such as user friendliness, perception and performance of the tool are tested, including aspects such as navigation, distance, scale, proportions, perspective, efficiency, interpretation and experience. Usability tests in more

Table 2. Types of usability studies.

Types of usability studies	Examples of articles
User needs analysis	Al-Douri (2010); Appleton and Lovett (2005); Drettakis et al. (2006); Schively Slotterback (2011); Stahre et al. (2008); Paar (2006)
Experimental studies in simulated settings	Billger et al. (2004); Crawford (2006); Cubukcu (2011); Dawood and Sikka (2008); Drettakis et al. (2006); Gill et al. (2013); Hannibal et al. (2005); Jacob et al. (2012); Laing et al. (2009); Lewis (2012); Mavridou (2012); Roupé and Gustafsson (2013); Roupé et al (2014); Stahre and Billger (2006); van Lammeren et al. (2010); Wridt (2010)
Experimental studies in real planning process	Senbel and Church (2011); Sunesson et al. (2008); Westerdahl et al. (2006); Wissen Hayek (2011)
Prototype studies in simulated settings	Ashraf Khan and Dong (2011); Bennett et al. (2012); Bishop et al. (2013); Boroushaki and Malczewski (2010); Kjems (2004); Lai et al. (2008); Long et al. (2011); Pettit (2005); Pettit et al. (2006); Poplin (2012, 2014); Rinner and Bird (2009); Roussou and Drettakis (2005); Saad-Sulonen and Botero (2010); Stahre et al. (2008); te Brömmelstroet et al. (2013); Thaung et al. (2012); Zhang and Fung (2013)
Prototype studies in real planning process	Kahila and Kyttä (2010); Long et al. (2011)
Process	Bailey et al. (2011); Pettit (2005); te Brömmelstroet (2012); te Brömmelstroet and Schrijnen (2010)
Implementation	Gupta et al. (2012); Halttunen et al. (2010); Horelli and Wallin (2010); Johansson (2012); Kyttä et al. (2013); Schively Slotterback (2011); Shen and Kawakami (2010)

real situations focus on factors such as usage, immersive experience and interaction. Some studies, carried out both in simulated and real settings, have specifically focused on the improvement of the dialogue process as well as learning, collaboration and cognitive aspects. A few studies have focused on evaluation technique and effectiveness (Bishop et al., 2013; Brown and Kyttä, 2014; te Brömmelstroet, 2012).

Intended target groups are often involved such as planners and various stakeholders participating in the dialogue process (decision makers, or citizens of a specific area). Other groups of participants include, for example, children, youths, unspecified professionals, the public, researchers, architects and students.

Which problems are stated concerning data handling and representation?

Urban planning and dialogue processes deal with analysing and presenting complex issues. This means gathering various kinds of data. Data may be derived from different sources, such as statistics, measurements, observations, questionnaires, 2D or 3D representations (sketches, drawings, etc.), voice recordings and sensors.

Demographic data about the inhabitants and quantitative measurable parameters include, among others, noise, sound barriers, air pollution, meteorological and microclimatic conditions, energy consumption, water and waste flows, traffic and the environment, traffic speed and accessibility to public transportation (i.e. Pack, 2010; Pelzer and Geertman, 2013; Stahre Wästberg et al., 2013; Wang and Li, 2010). There are also examples of visualization platforms that include social parameters, i.e. human experiences of factors such as safety; sense of place; well-being; happiness; and aesthetics (Kahila and Kyttä, 2010; Kyttä et al., 2013; Rixon and Burn, 2008; Staffans et al., 2010). These data are subjective, and thus require that human experiences are investigated and interpreted. Big data is another area of concern (Batty, 2013; Batty et al., 2012; Benenson, 2011; Cheshire and Batty, 2012).

How data is represented is connected to the development of models representing the physical environment (ranging from maps in 2D to 3D city models), as well as to the visualization of different kinds of data as described above.

Issues that have been investigated regard for example better integration of 3D surface properties into geovisualization systems (i.e. Heo et al., 2013; Lorenz and Döllner, 2010; Nebiker et al., 2010); handling of different types of data; navigation techniques; smart interaction with 3D city models (Döllner, 2009); and automatisation of transformation of different textures expressing various levels of realism (Döllner et al., 2005). Another research issue is how to compress data for faster transmission, since 3D city model systems include large amount of data (Wu et al., 2010).

A further issue concerns how to find the appropriate level of realism and detailing to use for a specific purpose, for example when it comes to experience the spatial surroundings (Cubukcu, 2011). The visualizations have to be able to interpret some issues exactly (Drettakis et al., 2006), while merely sketching others (Lange, 2005). In some cases, a small to modest amount of detail is sufficient for obtaining the level of realism needed to operate the tool (Pettit et al., 2006). Others conclude that graphical complexity is preferable to a loss of information in detailing (Ostermann, 2010; Stahre et al., 2008). If the information is too complex, contains too many parameters, or is too abstract, it will be difficult to grasp (San José et al., 2011; Stahre Wästberg et al., 2013; Wissen Hayek, 2011). It is pointed out that to complement higher resolution imagery with tabular data and graphs in participatory decision making tools may increase the understanding of the material (Bennett et al., 2012).

Another issue is related to the experience of the 3D model, in terms of size, distance, speed, graphics and perspective. Physical objects rather than the spatial experience are often emphasized in common digital tools for visualization (Balakrishnan et al., 2007). In current rendering techniques, great achievements are made in representational similarity with a corresponding real world appearance through increased photorealism. In rendered images, light and colour can today be created with high visual realism. However, in models used for creating interactive 3D environments the focus lies on realistic volume and texture representation rather than achieving photorealistic light and colour appearance.

Apart from photorealism, colours and objects can also be used in a 3D city model in a symbolic way, or in sketch style expressions adapted to different phases of a design process. A special problem is how to combine photorealism and symbolism using colour in the same 3D model (Lange, 2005; San José et al., 2011; Stahre et al. 2008; Stahre Wästberg et al., 2013; Wang et al., 2008).

Increasingly perceptional aspects are included in digital modelling and visualization, instead of just focusing on the physical correctness of object representation (Billger et al., 2004; Stahre and Billger 2006; Thaung et al. 2012).

Regarding the choice of viewpoints, it is an advantage to be able to change perspective and scale in a 3D model (Billger et al., 2004; Kjems, 2004; Stahre et al., 2009), and multiple views are important in virtual environments (Drettakis et al., 2006; Morello and Ratti, 2009). In 3D city models, an aerial perspective is commonly used, which gives an overview of the content, but does not always provide the details necessary for understanding a project proposal in the planning process (Stahre Wästberg et al., 2013).

Which problems with development and implementation of digital visualization tools are pointed out in the articles?

Problems are stressed concerning potential misuse, misinterpretation and misempowerment with visualization tools. There is a risk that judgmental biases arise within the virtual space. Interpretation and use of images may be influenced by prior experiences, intentions and preferences (Appleton and Lovett, 2005; Neto, 2006). For that reason it is important to have knowledge on how different settings in and around the VR medium influence the experience of the shared visual space that the VR medium strives to achieve (Mavridou, 2012; Neto, 2006; Roupé and Gustafsson, 2013). In extensive usability studies, Roupé (2013) examined how different stakeholders experienced the 3D modelling medium, and pointed out both its usefulness and its bias problems. Moreover, the ''wow effect'' of a visualization can affect people's judgment of what is shown (Kjems, 2004). The problem thus lies in discovering how the message can be conveyed in a way that maximizes comprehension while minimizing the risk of incorrect interpretations.

The interaction with the 3D model, such as the way of steering (mouse, touch, eye tracking, and kinetics), and different choices of display techniques (goggles, big screens, cell phones), varies. When navigating in the model there can be a choice between camera rides, free movements and lighting and switching off information. Haptic feedback, compared to visual feedback, can increase for example the navigation of a user by enhancing the memory of the walked through area (Jacob et al., 2012). Kinectics, i.e. how the human body interact with the virtual environment, enable a more natural and user friendly way of interacting with the virtual environment (Roupé et al., 2014). Results showed that the interface in relation to mouse/keyboard interaction enhanced learning, understanding and spatial reasoning of the participants (Roupé et al., 2014).

Problems that are stressed concern the management of newly developed visualization tools in established organizations. Such problems can for example concern ownership, management, maintenance and accessibility. One investigation of available resources for planners showed, for example, that organizations have resources for web design, but not for Internet based mapping technologies, and that smaller municipalities may lack the budget or resources for visualization (Schively Slotterback, 2011). Several of the developed visualization tools for dialogue require expert knowledge, such as a specially trained technician, for usage and maintenance, which may prevent a planner from using them. However a great deal of development is needed before such tools can be adapted for use by non-experts.

In several projects, tools are developed as a close joint collaboration between researchers from different disciplines and urban planners. In some cases this may cause problem with the long-term implementation. The development of the Swedish tool *Urbania* clearly exemplifies this. *Urbania* was developed in the transdisciplinary project *Urban Games* commissioned by two partners.[9] It was tested in real planning processes by the Swedish Transport Administration and in citizen dialogue processes by the City of Gothenburg. For the past two years, an ongoing discussion has concerned who owns, and has the intellectual property rights to the tool, that is, whether a company should be created to run the tool or whether one of the partners should own it. In the meantime, the tool has been available for researchers in selected projects.

Other problems that are stressed concern the importance of developing and evaluating dialogue processes, which is crucial to successful usage of the tool (Bailey et al., 2011; Brown and Kyttä, 2014; Horelli and Wallin, 2010; Senbel and Church, 2011; te Brömmelstroet, 2012; te Brömmelstroet and Schrijnen, 2010). Citizens should be informed about the decision making process, the limitations of public process and the limitations of the tools themselves (Senbel and Church, 2011). Brown and Kyttä (2014) propose the need for exploring the use of these planning systems throughout a complete planning cycle. They propose to explore and analyse success stories of adoption and integration of PPGIS in public sector planning, in order to find the enabling factors. Poplin (2014) pointed out that the use of gaming in dialogue processes is one way to engage and motivate people. Gordon et al. (2011) and Gupta et al. (2012) state the importance of creating increased immersiveness in planning processes which may be gained by game based learning.

Further problems related to the implementation of visualization tools for dialogue are the building of knowledge, which is prevented by insufficient feedback and follow up (SOU, 2012; te Brömmelstroet, 2012). Moreover, stakeholders should be included in the process of evaluating the success of plan implementation (Morckel, 2010).

Summary of our answers to the guiding questions

What kind of digital visualization tools for dialogue in urban planning processes can be found in the research literature? A wide range of visualization tools for dialogue has been found; either based on 2D maps, 3D environments (including 3D city models and VR models) or gaming. The use of VR and interactive real time rendering in urban planning and building design is becoming more common, and gaming, as well, appears more frequently in planning processes. AR, and the field of multi sensors, are considered having great potentials, but are still in their infancy.

Who develops for whom? The initiators of the development originate from different areas, such as GI science, computer graphics, 3D modelling, VR, interaction design and urban planning. The closer to a real scenario in which a tool is tested, the more collaboration exists between researchers and practitioners. Different kinds of visualization tools are developed by companies and organizations outside academia, thus contributing to the development of the field. These activities are seldom documented and hardly published in scientific literature, but can instead be, however only partially, found at company websites.

How is usability evaluated in tool development processes? There has been an increasing amount of usability studies during recent years. There is a tendency for the usability studies to have gone from experimental and prototype studies to more and more concern real planning processes and implementation. Studies of implemented tools in real planning processes are, however, still rare. The trend points toward an upsurge in implementation studies within real planning processes. An issue here is that usability studies still are time consuming, since real projects and processes usually do not follow the time frames of the research projects.

Which problems are stated concerning data handling and representation? Regarding the reliability and complexity of the visualization tools, it is important to promote social dimensions in dialogues based on visualization tools to the same degree as quantitative data. One issue is to determine how qualitative and quantitative data can be connected in the tools. Data must be presented in an interesting and easily comprehensible way. This regards appropriate levels of realism and detailing, as well as the user's experience of and the appearance of the digital models. The problems of symbolic and realistic features in the same tool concern, for example, how plan and street views can be integrated in the same model and how colour can be used for different purposes.

Which problems with development and implementation of digital visualization tools are pointed out in the articles? Misuse, misinterpretation and misempowerment of visualization tools are seen as potential problems. The implementation, and management of new visualization tools in established organizations may cause problems with ownership, maintenance and accessibility of the tool. Several of the tools for dialogue require expert knowledge, which might be a barrier for successful usage. Finally, it is important to develop and evaluate dialogue processes, as insufficient feedback and follow up prevents knowledge building.

Five identified challenges for implementation of visualization tools

Based on the stated problems, the following challenges for implementing visualization tools have been identified: The challenge of integrating data; of representing data; of avoiding misinterpretation; of organizational changes; and of engagement.

The challenge of integrating data

One of the important challenges faced when trying to create effective dialogue processes is how all the parameters that are relevant to a planning process can be visualized and acted upon. The Swedish Delegation for Sustainable Cities (SOU, 2012) stated the importance of balancing qualitative, social, or so called ‘‘soft’’, values with more quantifiable physical or so called ‘‘hard’’ parameters. The term *social* includes all aspects of human experiences of and relations to the surrounding world, such as spatiality; safety; crowdedness; comfort; and attractiveness. SOU (2012) also stated that it is easier for societal sectors that are usually supported by quantitative data and physical measurements (e.g. energy and transport sectors) to claim their interests, than it is for sectors representing human experiences, which are harder to quantify (e.g. cultural and social sectors). It is therefore important to develop integrated planning models in order to combine physically measured data with, for example, the experience of safety and comfort in an urban environment on the same platform. Values such as health; social equality; justice; safety; and architectonic and urban spatial qualities need to be highlighted and made influential in transition processes.

One important challenge is how we can gather, handle and visualize the huge quantities of data found in society today. Data is increasingly about reductions and interactions, and understanding big data is a major challenge (Cheshire and Batty, 2012). One characteristic of big data is that such data is related to groups rather than individuals (Batty, 2013). Methods are needed to integrate traditional datasets with crowdsourced data, where there is less control (Batty, 2012). Future challenges will be found in research on Smart Cities (Batty et al., 2012). Spatial simulation methods that make use of big data are being developed (Benenson, 2011). Future development points towards interactive websites and geo portals as well as the wikification of GIS (De Longueville, 2010).

The challenge of representing data

This challenge concerns how to visually represent information through digital models. The strive for photorealism that drives the technical development within computer graphics is not always in concordance with the need within urban planning to create trustworthy virtual environments for conveying understanding for the proposals. Instead, to create trustworthy virtual environments in the process of forming a design idea, there is a need for different expressions and levels of detailing in the representations. Different types of representations fit different phases of a design, and one challenge concerns how different computer generated representations can be integrated into the process. A specific problem is how colours and objects can be used in a 3D city model, both in a symbolic and in a realistic way.

When it comes to interactive visualizations, there is a need for increased awareness regarding the use of light and colour; and of appropriate levels of detailing and realism.

Three-dimensional visualizations can be highly communicative and illustrative, however the spatial differences in a 3D model, in terms of scale; size; distance; speed; graphics; and perspective, compared to reality affect the experience of the virtual environment. To make a user observe a specific detail or a certain phenomenon can be difficult due to the fact that a virtual setting consists mainly of visual impressions, restricting active investigation and preventing the sense of real presence. Another factor to consider is the different requirements of the street level perspective and the planar view, as well as finding relevant choices of viewpoints.

There has been much focus on the development of techniques for representing similarity through increased photorealism. Accordingly the challenge lies in developing experimental expressions in concordance with a corresponding real space, i.e. to integrate alternative expressions when photorealism is not sufficient and to combine different expressions such as photorealism and non-photorealism in the same model. Specific challenges include how to integrate different kinds of models and seamlessly switching between levels of detail, as well as to discover how a sufficient level of trustworthiness can be achieved in the visual appearance.

The challenge of avoiding misinterpretation

Visualizations can be interpreted in a way that was not intended. For example, when high photorealism is used, a sketchy proposal can be understood as a fixed solution. Hannibal et al. (2005) pointed out that a high level of realism could lead to an overly definite and non-negotiable expression, thus suggesting that the project plans cannot be changed. Too much detail and visual realism in visualizations at the initial stages of a planning process are often not necessary and can even be misleading, as that information will not be decided on until a later date (Neto, 2006).

The use of digital models for conveying design solutions must be done in a balanced way in order to achieve effective design communication, especially with the general public (Neto, 2006). This is because computer visualizations and imagery may capture the attention of viewers, but may not necessarily enhance their critical awareness, i.e. design communication should not merely be a matter of the built environment's appearance. For example, the choice of viewpoints and the use of techniques to direct attention are important. Appleton and Lovett (2005) and Neto (2006) have stated that images are influenced by the producer's intentions and preferences. These factors may cause potential misuse.

The challenge of managing new visualization tools in established organizational structures

Questions regarding the implementation visualization tools are often thought to be outside everyone's area of responsibility, which may lead to no one adopting the tool (Pettit, 2005). This can be partly related to the job classification structure in organizations, which may make it unclear where visual activities are located organizationally. Access to the technology and disconnects between planners and IT staff are examples of other organizational difficulties (Schively Slotterback, 2011). This may be due to the need for expert knowledge for the use and maintenance of the tool. Joint development of tools between researchers and stakeholders in urban planning processes can generate problems when the tool is implemented in a practical context. Such problems can, for example, concern ownership;

management; maintenance; as well as accessibility. According to Horelli and Wallin (2010) the digitalization of planning processes thus far has been based on a top-down approach, which obstructs the development of new approaches and methods. They pointed out that the new approach to e-planning within community development is anticipatory, formative and action oriented.

The challenge of developing engaging dialogue processes

Research shows the potential of visualization tools in dialogue processes. However, different kinds of tools are suited to different parts of the process or different types of encounters. The challenge concerns the importance of developing the actual dialogue process, which includes aspects such as motivation and learning. Preconditions for a successful process include a good learning situation. For increased knowledge building in sustainable urban development, Kolb's learning model 'Experiential learning' supports the use of games and visualization (Kolb, 1999). Because gaming and visualization engage through images, text, and interactivity, they create possibilities to reach a broader group and cover more learning styles than a text or a lecture can. te Brömmelstroet and Schrijnen (2010) stressed the importance of realizing that a visualization tool in itself is not enough, but that a mediator is required who can design meaningful use of planning support systems.

The need for new methods of evaluating dialogue processes in implementation studies has been pointed out by te Brömmelstroet (2013), who has called for a more systematic approach; a common language; and development of measurable indicators. Bishop et al. (2013) propose a framework for evaluation of visualization tools based on a literature review and an extensive user study. Brown and Kyttä (2014) state in their recent overview the need to understand the barriers for implementation in the public sector. Research priorities are to improve the public participation and to evaluate the effectiveness in PPGIS.

Considering that the vast research field on spatial presence in virtual environments (Slater et al., 2002) has not been found in the literature on visualization tools for dialogue. This is a gap that needs to be filled in future development of engaging processes for dialogues.

Misempowerment, according to Senbel and Church (2011), refers to empowering individuals to act in an environment where their actions are meaningless. To engage the public with visualization tools may be problematic if tool usage incorrectly implies that, through it, citizens have free access to the planning process.

Conclusions

The driving force for development of visualization based tools for dialogue is the desire to support sustainable city planning through information sharing, analysis, development, presentation and communication of ideas and proposals throughout the planning process. Development concerns aspects such as technical improvement of the functions of tools; and improvement of the dialogue processes in terms of learning, collaboration and cognition. In this article, we have discussed the development and implementation of visualization tools for dialogue in urban planning. Through a systematic literature search we have looked for answers to questions concerning development, implementation and evaluation of visualization tools. Specifically we have focused on stated issues on data handling and representation of data. Out of this, five challenges for implementing visualization tools have been identified: *Integrating data*; *representing data*; *avoiding misinterpretation*; *managing visualization tools*; and *development of engaging dialogue processes*.

With faster computers, better simulation models and data collection methods, an increasing amount of available data, and increasing use of digital interaction tools, there is now a focus on collaboration and implementation. In this development, there is a need to consider how we can achieve the full potential of visualization tools and processes for dialogue, as well as how these can be implemented. Organizational preparedness is necessary, including clear ownership; resources for maintenance; and training in handling the tools.

The articles either point out societal challenges to address the usage of visualization tools, or concern the role of visualization in urban planning. The societal challenges addressed are, for example, sustainable urban development in general; the role of big data; and visions concerning tool development within various application areas. While in this study the focus has been on an urban/city context, our conclusions can largely be translated to any participatory planning exercise.

Finally, it is important to bear in mind that tools alone, though useful as they are, are not enough for a successful dialogue process.

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Notes

1. The matrix with the coded text can be obtained from the authors. The text was coded in either English or Swedish.
2. minstad.goteborg.se/
3. https://communityplanit.org/
4. http://blockbyblock.org/, http://vimeo.com/68377213
5. aurin.org.au
6. Softgis.fi
7. https://maptionnaire.com/
8. http://placeofsocialmedia.com/page/2/
9. Partners within the centre Mistra Urban Futures http://www.mistraurbanfutures.org/en

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