Lange, E. (2011) *99 volumes later: We can visualise. Now what?*, Landscape and Urban Planning, 100 (4), pp. 403-406
http://dx.doi.org/10.1016/j.landurbplan.2011.02.016

Elsevier Editorial System(tm) for Landscape and Urban Planning
Manuscript Draft

Manuscript Number: LAND-D-11-00001R1

Title: 99 volumes later: We can visualise. Now what?

Article Type: 100th Volume SI

Keywords: 3D landscape visualization; visual simulation; virtual reality; augmented reality; landscape planning; landscape design

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Abstract: The early years of the journal Landscape and Urban Planning, then called Landscape Planning, coincided with the start of the era of digital landscape visualizations. This paper examines this journal's articles on landscape visualization published over its 99 volume history (1974-2010). This work has contributed to representation, assessment, and decision-making in landscape planning and design. Technological advances are noted, as are case studies and research topics and questions considered to be important at the time. This work is then looked at in the context of subsequent developments in the field of landscape visualization in terms of distinct research areas, directions, and topics reflected in the publications. From this analysis, the paper presents an outlook on future challenges for research and practice that includes themes such as the diffusion of 3D visualization in our everyday environment, linking visualizations with underlying models, going beyond highly-realistic but simply descriptive visualizations, using visualizations in an assessment and decision-making context, and incorporating multi-sensory experiences. It also considers the prospects for further technological advancements such as augmented reality for making decisions in planning and design of our future environments.

1. Introduction

"Landscape and urban planning" are words selected as the name of this journal but also refer to activities concerned with natural and urban environments of the past, present, and most importantly, the creation of future environments. As an interdisciplinary focus of concern, both the journal and activity of landscape and urban planning deal with the study, analysis, planning, and design of biophysical and social environments that express a range of sensory qualities. Humans in turn possess a suite of perceptual systems that allow them to sense these qualities: an auditory system (the sense of hearing), a tactile system (the sense of touch), a kinaesthetic system (the ability to sense and coordinate movement), a vestibular system (the sense of balance), an olfactory system (the sense of smell), a gustatory system (the sense of taste) and a visual system (the visual sense). Of all the senses, the visual sense is by far the dominant component of human sensory perception (Bruce et al. 1996). Fortunately, for landscape and urban planners and designers, the visual environment with its range of visual stimuli can be represented via a palette of analogue and digital media as an essential means for communicating to experts and the public in planning and design.

This paper examines this journal's articles on landscape visualization published over its 99 volume history (1974-2010), and the contribution to representation, assessment, and decision-making in landscape planning and design, also in the wider context.

2. Technological advances

Within only a few decades, contemporary Western society has evolved from being dominated by digital immigrants hesitant to embark on a digital landscape journey to a society and professional world now dominated by digital natives. In this short timespan, tools and techniques for representing our world in three dimensions using 3D visualization have diffused throughout our everyday environment. Unborn babies can be seen in 3D ultrasound. Children only a few years old are already playing with 3D computer games, as are young adults, parents, and even some grandparents. These multiple generations can watch the weather forecast together in 3D, possibly on a new 3D TV screen; enjoy a multi-sensory 4D cinema and other futuristic movie experiences; travel to remote areas using a satellite navigation system that shows the environment in perspective view; and use Google Earth to explore remote environments through data streamed over the Internet (cf. Sheppard and Cizek 2009), showing 3D representations of the whole globe enhanced with information-tagged imagery. As landscape and urban planners and designers, how will we cope with the raised expectations of this new cohort of visual sophisticates?

While in previous decades visual representation techniques were only very sporadically utilised, they have now become a standard in landscape research and practice. The array of techniques at our disposal is broad, and their evolution from physical models, drawings or paintings, perspective views, and analogue photomontages to digital photomontages, virtual reality, Internet-based visualizations and augmented reality is impressive. 3D landscape visualization has developed from an extremely costly and therefore restricted technology requiring specialized equipment and labs into an essential tool for landscape design, planning and management that can be accessed in the field on small tablet computers and mobile phones. Sophisticated 2D and 3D software is even available for free.

Also within the last few decades, digital landscape representations have developed from very abstract and static representations to highly realistic visual representations capable of being explored through dynamic spatial movement, possibly providing an immersive experience in multiple spatial and temporal scales.

Digital 3D visualizations have now become a common feature in landscape and urban planning, in reference to both this journal as well as the actual activity. The use of visual representations based on digital or virtual environments is well established in planning statements, as part of Environmental Impact Assessments, design competitions, and site development (just think of all those large display boards one sees these days showing a design proposal posted next to the actual construction site). In each of these cases, the purpose of the visualizations is to communicate with the public or with potential clients. To a certain degree, and not studied by the research community so far, visualizations also serve an internal communication function among experts of different (or the same) disciplines working on a joint project. Typically, in terms of their content, landscape visualizations still focus on the outcome or final product of a planning and design process.

3. Case studies and areas of research: A timeline of published articles

In the early 1970s, the US Forest Service was a major driver in developing new methodologies for landscape assessment as well as new techniques of landscape representation. The first published paper in this journal that introduced 3D computer graphics was thematically focused on the visual management of forested landscapes over time (Myklestad and Wagar, 1977). However, most parts of the paper concentrated on the technology itself. Rather abstract tree and ground cover symbols were used to communicate landscape changes caused by timber harvesting. It was published only two years before the highly influential 1979 Lake Tahoe conference ‘Our National Landscape’ (Elsner and Smardon 1979), which at that time included the state-of-the-art on methods of digital landscape representation and landscape assessment.

In the early 1980s, in Berkeley, Syracuse, and Lund, “modelscopes” comprising a miniature lens and camera hung from overhead gantries enabled researchers to explore alternative planning scenarios within analogue, physical models and to study urban landscape perceptions from a visual as well as dynamic perspective (Smardon 1988).

In 1990, digital photomontages and photo editing, nowadays standard tools of landscape architectural education and practice as well as landscape research, were for the first time introduced in *Landscape and Urban Planning* to explore vista management options in Acadia National Park in response to anticipated landscape change (Lange 1990).

Since 1990 there have been three major Special Issues of *Landscape and Urban Planning* published that have helped spur increased interest in landscape visualization and modelling in the research community for assessing, planning and designing landscapes. The first focused on “Data Visualization Techniques in Environmental Management” (Orland 1992) and addressed visualization linked to the modelling of environmental systems including air pollution, fire history, ozone concentration, ocean currents, and forest pest impacts. While the modelling-visualization linkage is still a major area for research with unresolved issues, especially considering real-time interactive approaches, since then many of the basic technical difficulties that were pointed out in terms of software, hardware and data have now largely been resolved.

A second Special Issue appeared shortly thereafter and focussed on “Landscape Planning: Expanding the Tool Kit” (Bishop 1994). It covered new approaches to GIS-based landscape visualization and modelling and introduced the new concepts of cellular automata and autonomous agents. Cellular automata act based on rules affecting neighbouring cells of a grid, while autonomous agents are able to pursue programmed goals (such as finding a route on a mountain top), which can also include learning or communicating with other agents.

The third and so far last Special Issue dedicated to this topic was from the 1999 Ascona conference ”Our Visual Landscape: Analysis, Modelling, Visualization and Protection” (Lange and Bishop 2001). It addressed landscape assessment, GIS-modelling, visual representation, and also perceptual issues in relation to digital landscape representation, including questions of realism and perception of simulated landscapes as well as representational validity and criteria (Bishop et al. 2001, Danahy 2001, Lange 2001, Sheppard 2001) that were cited as important topics for research by several authors in the earlier special issues.

The relative ease of use of digital photomontages (Lange 1990) led to a revolution in landscape preference research, allowing for investigators to digitally create images of alternative landscapes, instead of having to rely on photographs of existing landscapes, and systematically vary features, e.g. including all possible combinations of them in rigorous factorial designs. This has the advantage of being highly controllable in terms of the independent and dependent variables studied. The applications to landscape design and planning are numerous, as evidenced by a large number of research publications in this area (recently e.g. Lindemann-Matthies et al. 2010, Zheng et al. 2011). In landscape preference research this has now also extended to using virtual landscape models.

4. Outlook and further questions for research

There are a number of neglected or unresolved research areas that need further exploration. These include issues about the complexity and dynamics of the real world, human perception of landscapes, simulated sensory environments, new and emerging technologies, as well as landscape visualization for improved communication, public participation, and decision-making. Nowadays, the virtual environments that we create can be highly realistic representations of the real landscape including terrain, vegetation and built structures. Does it matter that representations of animals and humans and their movement as well as the dynamics of water, atmosphere, and light are less convincingly done? Perhaps. But it also depends on the questions that one would like to answer.

Regarding people's perception of landscapes, both real and virtual, there is a tendency to assume that an image is worth a thousand words and that images speak for themselves. However, we must also consider the nature of the perceiver and how landscape stimuli are perceived and interpreted. While different people may have different views and values associated with the real landscape that surrounds us, they might also have different views and values associated with virtual representations of existing or proposed landscapes that do not yet exist. Therefore, even the most realistic virtual representations that we create might not be perceived as we think they are perceived. Landscape visualizations are illusions, illusions of the past, present and future. We can judge the realism of landscape visualizations that portray existing conditions by comparing them with real places and in many cases the results will be surprising. A plan or design may look entirely plausible when visualized on paper or a computer screen but may feel and function quite differently when viewed as a real-world space. This challenge of realism is heightened when dealing with the re-creation of past landscapes and creation of future ones.

Issues that need to be considered in developing realistic visualizations include data availability, data precision, and the level of uncertainty in a proposed plan or design. In 3D visualizations uncertainty is typically not addressed. For example, the software and hardware available nowadays makes it possible to represent a development proposal as a 3D visualization in a highly realistic fashion. Often, in practice exactly this is done. However, at the early stages of planning and design many details are not necessarily confirmed or fixed. In such cases, “realistic” visualizations do not reflect this fuzziness, and therefore a more abstract visualization would be more appropriate. This still needs more systematic experimental research regarding the validity and the perception of such representations.

Clearly, in the last few decades we have witnessed major advances (seminal work e.g. by Appleyard 1977, Zube et al. 1987) in how we represent the visual landscape, how we assess it, and how we use visual simulations and virtual landscape representations in environmental decision-making. Although the visual sense is by far the most important human sense, focussing only the visual provides us with a sectoral ‘view’, literally, of our environment.

What we are lacking is an integrative multi-sensory approach. Beyond the dominance of the visual sense, we know very little about the role other senses play in landscape perception and experience or of the interrelation and interplay among our senses. We know even less about how to represent a multi-sensory environment, how such representations might influence landscape assessments and how they could influence decision-making in planning and designing our environment. For example, the view of a very beautiful existing or proposed landscape can be adequately represented in visual terms--as printed in reports or online via the Internet--and assessing such a representation solely on visual quality will likely generate uniformly high scores. But what if next to this viewpoint is a highway or an airport generating a high level of ambient noise? A waste dump site or a farmer spreading manure? This poses a range of technological problems in terms of sensory representation, but it also raises serious planning and policy issues on how to deal with multiple and conflicting landscape values. Is a beautiful view of a landscape located next to a smelly waste dump site better or worse than a mediocre landscape view without any odorous impact? And what if some noise is added as well? In our multisensory world, decisions can quickly become complex.

While such considerations may be important to landscape and urban planning research and practice, there are high technological hurdles that need to be overcome for an entire artificial representation of our sensory experiences in a laboratory environment. But perhaps such a strategy is unnecessary. Considering the ubiquitous access that people have to mobile phones that are able to display 3D graphics, and given increasing access to high-capacity mobile phone networks, it is likely that in the future we will not just be able to represent, assess, and make decisions about our environment in a remote office or lab. Newly emerging technology such as mobile phone augmented reality (figs. 1 and 2) expands the currently available planning and design toolkit, allowing us to provide people with an augmented view of the real world on-site, where proposed changes can be seen in the context of a fuller ambient array of sensory experiences. While such technology may take time before it becomes a standard approach in planning and design, augmented reality holds significant promise in expanding our ability to more fully represent the multisensory characteristics of landscapes.

Further developments in landscape visualization will have an impact towards improved and more informed public participation as supported by visualization technology for communication between policy makers and non-experts (e.g. mobile phone augmented reality allowing the streaming of data of planning proposals while one is on-site), improved integration of the visual landscape quality in decision-making in planning and design, and a forward-looking, pro-active approach to making decisions about our future environments. This involves further work regarding the use of 3D visualizations in terms of relevant phases of planning and design, audience, the level of engagement, as well as questioning the still existing focus on the representation of the final product of planning and design ('the icing on the cake', cf. Orland 1992). Instead, what we need is a more 'playful' and experimental approach to planning and design with an emphasis on the process, involving relevant stakeholders early-on, and thereby possibly improving the outcome.

Also, recently the general public is increasingly gaining importance in landscape visualization as suppliers of freely accessible 3D models and visualization materials, e.g. through Google Earth and SketchUp warehouse which can be seen as a major shift in the field and which will need further research exploration.

Finally, landscape visualization needs to move beyond focussing on the physically perceivable environment and towards linking 3D visualizations with climate change models, flood models, ecologic models (e.g. Hehl-Lange 2001), economic models, and other tools pertinent to landscape and urban planning research and practice as well as potentially being a powerful tool to project future consequences for many disciplines and sectors.

In a different but equally important direction, it might be worth investigating the connection of virtual or augmented reality with social reality including new approaches to communication such as blogs, forums, and social networks. These interesting possibilities leave us with a large uncharted research territory to be explored for both the field and the journal of *Landscape and Urban Planning*, expanding the scope and significance of our work and providing new opportunities for collaboration with a broad range of disciplines and professions.

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Figure 1

Figure 1 Mobile phone augmented reality. For spatial reference, notice the railing in the visualization and in the real world. In the future, will we all be using our mobile phones to look at planning proposals on site?

Figure 2

Figure 2. Mobile phone augmented reality. The real scene is captured by the camera of the mobile phone. A proposed new park is aligned to the real world scene, also while moving the mobile phone and changing the viewpoint.

Graphical Abstract

Mobile phone augmented reality. For spatial reference, notice the railing in the visualization and in the real world. In the future, will we all be using our mobile phones to look at planning proposals on site?

Acknowledgments

Augmented Reality viewer courtesy by Dr. Ed Morgan, Deliverance Software Ltd. Data and model by the URSULA research project, Engineering and Physical Sciences Research Council UK.

***Short Author Biographies**

Dr. Eckart Lange is Professor and Head of the Department of Landscape at the University of Sheffield. He is a Member of the Scientific Committee of the European Environment Agency (EEA), Copenhagen, Denmark, in the area of Spatial Planning and Management of Natural Resources and an elected Academic Member of the Landscape Institute (Royal Chartered Body for Landscape Architects in the United Kingdom). His research focuses on how landscape and environmental planning can influence and direct anthropogenic landscape change, while developing innovative methodologies of how advanced virtual landscape visualizations and modeling can be used to explore human reaction to these changes.