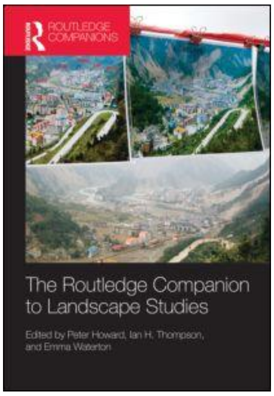

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Visualizing landscapes

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History of landscape visualization

For reasons of artistic merit or decision making, people have always striven to capture the essence of both natural and built environments that surround them. Wall paintings created by the ancient Egyptians capture long lost gardens in pictorial form, such as the garden of Sebekhotep found on a tomb wall in Thebes (Carroll 2003: 17). These early images mix together plan, elevation and bird's eye viewpoints, making it hard for the modern eye to interpret (Gothein 1966). However, the acceptance and consistent usage of perspective in the Renaissance period contributed to more accurate depictions of landscapes, leading to the creation of images that resemble the real world rather closely. Audiences in the late eighteenth and early nineteenth centuries were amazed by the creation of Eidophusikons, 'moving' pictures created by eighteenth-century English painter Philip James de Loutherbourg, dioramas or large-scale panoramic paintings. These can be seen as the equivalent of IMAX cinemas of today. Related to these developments is a more abstract form of landscape visualization; cartography, which also has a long and rich pedigree (Ehrenberg 2005).

Historically, capturing landscapes in images was driven by artistic, political or martial needs, but it is also possible to impart how landscape may come to look through these methods. Important early examples of this are the 'Red Books' of landscape architect Humphry Repton (1752–1818), who created water colours of existing landscapes and his future vision of changes, utilizing a system of painted overlays on flapped hinges (Repton 1980). These provided his clients with an easy to use 'before' and 'after' comparison of a proposed change to their estates.

As photographic technology developed and became affordable at the turn of the twentieth century, it became possible to capture existing landscapes far more rapidly than via drawing or painting. As a technical refinement the *photomontage* technique allowed new landscape features to be overlaid on to existing photography through manual etching or drawing on the photograph.

Figure 35.1 1:1200 scale model, Yantai, China; note the size of the person in the door at the top left corner.

In addition to the two-dimensional representation of landscapes, physical scale models, constructed from wood, card and so on, have been used to capture the spatial relationships of landscapes (Figure 35.1). They have been used to simulate journeys through landscapes using microscopic cameras, e.g. to record on video tape. While scaled models are normally used in practice, on occasion even a 1:1 representation – that is, a real world model – is produced, as shown in Figure 35.2.

Towards the end of the twentieth century the availability of desktop computers allowed digital techniques of landscape visualization to become more pervasive in presenting and

Figure 35.2 Berlin, Potsdamer Platz, 1:1 scale model.

conveying change to landscapes. Rather than hand-drawing plans, landscape architects began to employ computer software to draw, display and print their designs. With the advent of digital photomontage software photographs could be composited together (Lange 1990), and this technique has flourished since.

Computer Aided Design (CAD) and Geographic Information Systems (GIS) software tools have had a significant effect on the visualization of landscape, allowing the creation of 3D landscape models on computers. Initially, due to the constraints of computer processing power, these models were used to support the creation of more accurate photomontages as well as to create pre-rendered animated walk-throughs of places, which give the viewer a sense of motion through a landscape (Lange 1994). Also, with the ability to create and analyze complex spatial data, it became possible to deliver consistent high quality plans and maps of landscape change. The maps and plans output from this style of software are now commonplace in planning proposals. As remote sensing techniques have developed, vast data sources for mapping and aerial photography have become more common. Within the past decade, these data sources have become accessible via the internet, such as Google Maps, Google Earth and Microsoft Bing Maps.

Although the digital revolution had led to a radical change in the techniques and tools that could be used to create landscape visualization, the results still present snapshots of landscapes. These stylized representations of landscapes are useful to communicate information about landscape change, but they do not mirror the way people experience the real world. People rarely take a bird's eye view of a landscape and landscapes are not static, they are experienced dynamically and they change over time. For non-specialists, abstract and fixed representations can prove difficult to interpret and the choice of viewpoints and what is visualized in them may not be entirely representative of a scheme, especially if the visualizations are designed to market an idea. For example, Tufte (1997) highlights that Repton altered scales and added unnecessary embellishments to some of his before and after drawings. So, there exists two possible forms of disconnection from a portrayed design; visualizations constructed in a misrepresentative way (deliberate or not), or a failure of viewers to interpret the visualization correctly. This applies to the whole range of analogue or digital landscape visualization.

In recent years, there has been a conjunction of specialized computer hardware and computing methods dedicated to the provision of real-time graphical environments, driven by the need for higher fidelity visualization and simulation. This has allowed people to create 3D landscape models that are becoming more visually complex and interactive, finally allowing people to move freely around virtual spaces taking any viewpoint they wish to observe in future landscapes, giving rise to detailed real-time eye level walk-throughs (Morgan et al. 2009). These provide far more in-depth exploration of the spatial nature of future designs.

So, a major question is how best to incorporate these interactive 3D technologies as suitable visualizations into existing practice and workflows to better support design of and communication of landscape change.

Creating interactive 3D landscape models

Construction of an interactive 3D landscape model requires three basic elements: a 3D model of an area; software that can take this model and display it in real-time; and computer hardware that allows the software to operate efficiently.

Whilst there are an increasing number of software packages available (Simmetry3D, Lumion, Biosphere3D) or converted computer game engines (Herwig and Paar 2002) that allow real-time interaction with 3D models and the requisite computer hardware becoming cheaper, a major difficulty for creating interactive 3D visualizations is that of model construction (Paar 2006).

When creating a 3D model, it is necessary to collect enough data that will allow the creation of the model to the level of detail required. Ervin (2001) suggests that a digital landscape model can be broken down into six elements: landform; vegetation; water; structures; animals; atmosphere. To elaborate, 'structures' include all built form and infrastructure, such as roads, while the 'animals' category includes humans.

Landform data can be acquired from a variety of sources, but the more detailed the source the more accurate the resultant model will become. Ribarsky et al. (2002) noted the increasing availability of aerial and ground based Light Detection And Ranging (LIDAR) capture systems that allow the acquisition of accurate location and physical form datasets that can be used to generate urban models. Data derived from the LIDAR data can provide a starting point for interactive modelling techniques.

A common practice is to overlay terrain models with the relevant aerial photography to present contextual information on the landform, as happens in Google Earth. This works well when the viewpoint of the terrain is far away, but has its limitations as the viewpoint gets close to the terrain. The foreground of visualizations is noted as being important for the degree of realism (Lange 2001). This implies it is important to add as much foreground detail as is possible to landscape visualizations, especially if the interactive 3D visualization is to provide eye-level walk-throughs.

Atmosphere can be defined using simple effects, such as placing a 'sky box' of appropriate textures that surround the landform model. Boulanger et al. (2008) demonstrated dynamic real-time lighting of natural scenes, where lighting can be interactively changed to provide realistic conditions. Vegetation, structures, water and animals can be placed on top of the landform model in their corresponding positions in the model, which can often be derived from vector mapping data.

The most traditional approach to the construction of a digital landscape model is to assemble all the elements of a model by hand using software to create generic 3D models (Baumann 2005). However, the cost of modelling in this fashion is linked to the complexity of the model: as the detail increases, the amount of construction time required also increases (Müller et al. 2006). This has led to the drive for the development of methods that reduce the time to create models of landscapes.

Hoinkes and Lange (1995) developed an automated process of creating 3D models from 2D data sets. Such a system requires a library of suitable 3D models to be available, e.g. vegetation elements and structures, like power lines, as well as built form. In recent years, commercial Geographic Information Systems (GIS) programs, such as ArcGIS 3D Analyst (ESRI n.d.) have also begun to contain such functionalities.

Procedural generation of models, or procedural modelling, is the process of algorithmically constructing models. In other words, a computer uses a pre-defined set of rules to take an input set of data and transforms this to the resulting model as an output. It is often used to create individual elements of models, such as built form (Wonka et al. 2003), or whole virtual environments, such as the IMAGIS system (Perrin et al. 2001), which generates large-scale 3D landscape models based on geo-referenced data.

Animals or humans in interactive 3D landscape models tend to be static or at most animated in simple fashion. Typically, real world movement patterns are not accurately represented. Animation of animals and people in interactive 3D landscape visualizations and the perception of these elements remains an area to be researched.

Landscape design and landscape planning

Lynch and Hack (1984) referred to 'virtual worlds' in the context of exploring change and designed alterations to a landscape:

> designers need to construct 'a virtual world', a model of what they know about a site and program, which allows possibilities to be tested quickly.
>
> *(Lynch and Hack 1984: 128)*

Lynch and Hack speak of the construction of 'a virtual world' (for clarification purposes, referred to subsequently as the *mental model*), within the mind of the designer. They propose that diagrams and physical models, traditional forms of landscape visualization, aid the construction of this mental model. However, since this quotation was written, there have been many advances in technology which have led to the possibility of using real-time 3D models within the design processes for landscapes (Bishop 2005). In essence, it is now possible to create digital virtual worlds that support Lynch's mental models, using interactive 3D landscape models.

Also, interactive 3D visualization techniques fit well in Steinitz's (1990) model of Landscape Change which breaks the process of design down into several passes through defined stages of modelling. At the level of Steinitz's Representation Models and Change Models for analysis of spatial alterations, 3D landscape models help designers answer the questions of 'How should the landscape be defined?' and 'How may the landscape be altered?'

Kibria et al. (2009) state that when viewing visualizations, people bring their education and experience to bear on the model. By collecting together designers, experts and stakeholders in collaborative design workshops and providing interactive 3D landscape visualizations, there is potential to improve the mental models of each participant through discussion. The ability to freely explore the spatial nature of landscapes gives interactive 3D visualizations the power to support discussion revolving around a mental model of a participant, which in turn may increase the comprehension of the other participants. By creating discussion, design trade-offs can be explored, which should lead to better design decisions and more transparent planning processes.

Currently, interactive visualizations of landscape are seen at the end of the design process rather than as a design tool for communication between the designer and the stakeholder. As it becomes easier to create and visualize 3D models, it becomes possible to include interactive 3D techniques that allow models to be easily altered as part of the design process. These flexible models allow designers to edit and change the underlying 3D landscape model, such as in the Smart Terrain system (Buchholz et al. 2006).

Landscape planning processes are methods for legitimizing and controlling anthropogenic impact on the environment (e.g. Lange and Hehl-Lange 2010). These processes have become more organized and prescriptive over time but supported by international initiatives, such as the Rio Declaration on Environment and Development, some of these process and planning authorities are becoming increasingly democratic, thereby attempting to take account of different views of people and organizations that would be affected by any proposed changes. Therefore, as people with less exposure to the interpretation of spatial plans are increasingly being consulted, interactive 3D visualizations will be able to play an increasingly important supporting role.

Consultation in landscape planning has long been supported by the more established visualization techniques, such as plans, sections, and photomontages. However, with interactivity in landscape models, comes the ability for people to take control over the visualization, such as the

Figure 35.3 Interactive landscape model providing the ability for stakeholders to take control over the visualization.

ability to move anywhere within the model (Figure 35.3). Therefore, there is the potential to deliver far more meaning to the user than a two dimensional image created by someone with their own perspective and agenda. Schroth (2007) concludes that interactivity in visualizations contributes to better understanding of scenarios by participants and to building credibility and consensus within a collaborative planning process.

Nonetheless, interactive models are not necessarily going to replace other forms of visualization, but can be used in conjunction with more traditional forms of landscape visualization to support the planning process. If some people find it difficult to interpret plans, one of the most common forms of visualization of landscape change, but are comfortable looking at 3D images, then providing easy to navigate links between these two forms of visualization may improve understanding of designs.

Just as the previously mentioned Egyptian garden art contains a confusing mix of perspectives which may obfuscate meaning within a drawing, so there is a danger of misrepresentation using modern visualization techniques. A longstanding goal of real-time computer graphics is to increase the realism of the images created. However, the more realism there is in an image, the more likely it is to be accepted as final and, therefore, in a landscape design process, it is advisable to adapt the degree of realism to adequately represent the progress of the design process (Kibria et al. 2009). Computer-based models should take this visualization of uncertainty in designs into account. Therefore, despite having the technology to show visualizations that are increasingly photo-realistic, it should not be used simply because it is possible (Bishop and Lange, 2005).

Where next?

A possible avenue to take for mitigating 'over realism' in visualizations is that of Non Photo-realistic Rendering (NPR). This is a set of computer rendering techniques that offer a way of presenting 3D landscape models in more abstract form. Images can be automatically generated from one model to look like they have been sketched, or drawn in a cartoon style amongst other effects (Coconu et al. 2006; Lesage and Visvalingam 2002; Nienhaus 2005). However, despite their resemblance of hand-drawn sketches there is little understanding of how these representations of landscape may be perceived by participants of the planning process.

There are also a number of interesting uses for these interactive 3D models beyond that of representation of spatial change. Increasingly, non-visual data is being included with these models to increase the amount of information that can be communicated to the viewer. Thus, with the addition of context specific information into the visualization it is possible to utilize the same models in other stages of the Steinitz (1990) model. For example, if a model was created that, when altering a river channel to improve flood protection, could display new flood levels visually, then this would allow the interactive visualizations to support the Process and Impact Model stage.

One approach to this is to overlay a 3D landscape model with coloured geo-spatial data sets. This visualization of non-visual elements allows the viewer to consider observed data within a 3D context, which may provide more insight into the data. Hehl-Lange (2001) demonstrated this technique with the overlay of ecological data, such as bat flight paths, within a landscape model. Isaacs et al. (2008) used falsely coloured built form to indicate individual building energy usage sustainability assessment within their interactive tool, S-City VT. Morgan et al. (2012) false coloured a 3D landscape model with a density function derived from bird sighting surveys, which was taken a step further by adding bird calls to the model with the frequency of calls based on the same density function. As the user performed an eye-level walk-through, they would experience bird calls based on observed data. Gill et al. (2010) demonstrated the incorporation of the results from a Bayesian Network that predicted the danger and enjoyment of a weir design for canoeists, into a 3D weir design tool that operated within the context of an interactive 3D visualization, shown in Figure 35.4.

Agent-based modelling computes the behaviour of independent rule-based units. The interaction of these individual units can produce overall emergent behaviours that are otherwise difficult to model, such as animal flocking and crowd simulation. Cavens et al. (2007) applied this technique to predict recreational behaviour of hikers in the Alps using a 3D landscape model, allowing agents to react to their physical environment.

In the field of architecture, there has been a movement from traditional 2D and 3D CAD techniques (Eastman 1976) to Building Information Models (BIM). These create a single

Figure 35.4 Interactive weir model in context within a larger existing landscape model.

repository of information about a building, which supports the lifespan of a building from design conception, through construction to ongoing maintenance. A BIM is built from basic components, such as walls and windows, which know how to draw themselves in both 2D and 3D. To create the BIM, these components are combined in 3D using parametric constraints, which form a structure to reflow elements when designs are altered. As each component can also hold non-visual information, analytical tools have been developed that can operate on the BIM, such as creating costing schedules. One of the stated advantages of creating this form of 3D model is that spatial design errors are reduced at the planning stage, rather than propagating to the construction stages. Ervin (2006) has suggested a similar approach is taken to landscape in the form of Landscape Information Models. The idea being that there would be one central model for a landscape that could be used for visualization, analysis and simulations. Whilst Laycock and Day (2003) suggested further work should take place integrating procedural modelling with more standard techniques to create a 'memory efficient realistic urban model', all of these approaches are still working towards the development of an integrated system. This system would not only generate the 3D landscape models and render real time views of a large area of landscape, but also have ability to zoom into detailed areas and provide functionality for editing at site level or strategic scale.

If interactive 3D landscape models that can be changed easily are married with predictive models and simulations, then it will be possible to develop LIMs that are capable of analysis and simulation of the effects of change and the visualization of the results of these in 3D stereo vision. Bishop et al. (2009) suggest an interactive visualization interface for forest management scenarios. It would allow the user to simulate different management strategies for forest management over long time periods whilst seeing the visual effects on forests in the landscape.

New opportunities arise for transmission of landscape visualization with the advent of 'smartphone' technologies that can derive their location, have high resolution screens, internet

Figure 35.5 Tablet device displaying a planning proposal on site.

connectivity and enough computing power available to render complex graphics. These devices are becoming more commonplace and present an opportunity to push landscape visualization to the public in an easily accessible manner. This has been demonstrated with 'apps' that can overlay information on video feeds, presenting augmented reality (Layar 2012) and apps that can present visualizations of future scenarios whilst walking through the area that would change (Lange 2011), as shown in Figure 35.5. It would seem for landscape architects, architects and planners that the ability to disseminate interactive 3D visualizations of their proposals via smart phones would be highly advantageous in reducing costs of delivery and increasing inclusiveness in decision making.

In summary, it seems that now more than ever it is possible to create detailed imagery of proposed changes to our environment through interactive 3D landscape models. With the mobile device method of dissemination becoming available, these will be consumed by more interested parties in more ways. Interactive 3D LIMs may aid creation of visually attractive, sustainable environments and these visualizations will serve as a historical record of our world and our values. Therefore, it seems that landscape visualization is more vibrant than ever and will continue to develop long into the future.

References

Baumann, H. (2005) 'Hayelberga: integrated real-time modelling and visualisation'. In Buhmann, E., Paar, P., Bishop, I.D. and Lange, E. (eds) *Trends in Real-Time Landscape Visualisation and Participation Proceedings at Anhalt University of Applied Sciences 2005*. Berlin: Wichmann, pp. 303–6

Bishop, I.D., (2005) 'Visualization for participation: the advantages of realtime'. In Buhmann, E., Paar, P., Bishop, I.D. and Lange, E. (eds) *Trends in Real-Time Landscape Visualisation and Participation Proceedings at Anhalt University of Applied Sciences 2005*. Berlin: Wichmann, pp. 2–15

——and Lange, E. (2005) 'Visualization classified'. In: Bishop, I. and Lange, E. (eds) *Visualization in Landscape and Environmental Planning: Technology and Applications*. London and New York: Taylor & Francis, pp. 23–34

——, Stock, C. and Williams, K.J. (2009) 'Using virtual environments and agent models in multi-criteria decision-making'. *Land Use Policy*, 26(1), 87–94

Boulanger, K., Bouatouch, K. and Pattanaik, S. (2008) 'Rendering trees with indirect lighting in real time'. *Computer Graphics Forum*, 27(4), 1189–98

Buchholz, H., Döllner, J., Ross, L. and Kleinschmit, B. (2006) 'Automated construction of urban terrain models'. In Riedl, A., Kainz, W. and Elmes, G.A. (eds) *Progress in Spatial Data Handling, 12th International Symposium on Spatial Data Handling*. Berlin: Springer, pp. 547–62

Carroll, M. (2003) *Earthly Paradises: Ancient Gardens in History and Archaeology*, London: British Museum Press

Cavens, D., Gloor, C., Illenberger, J., Lange, E., Nagel, K. and Schmid, W.A. (2007) 'Distributed intelligence in pedestrian simulations'. In: Waldau, N., Gattermann, P., Knoflacher, H. and Schreckenberg, M. (eds) *Pedestrian and Evacuation Dynamics 2005*. Berlin: Springer, pp. 201–12

Coconu, L., Deussen, O. and Hege, H.-C. (2006) 'Real-time pen-and-ink illustration of landscapes'. In *Proceedings of the 4th International Symposium on Non-photorealistic Animation and Rendering*, Annecy, France: ACM, pp. 27–3. Available at http://portal.acm.org/citation.cfm?id=1124728.1124734 (accessed 24 October 2012)

Eastman, C. (1976) 'General purpose building description systems'. *Computer-Aided Design*, 8(1), 17–26

Ehrenberg, R.E. (2005) *Mapping the World: An Illustrated History of Cartography*, National Geographic Books, Washington DC, USA

Ervin, S.M. (2001) 'Digital landscape modeling and visualization: a research agenda'. *Landscape and Urban Planning*, 54(1–4), pp. 49–62

——(2006) 'Landscape meta-modeling'. In Buhmann, E., Ervin, S., Jorgensen, I. and Strobl, J. (eds) *Trends in Knowledge-Based Landscape Modeling*. Dessau: Wichmann Verlag, pp. 2–15

ESRI (2011) *ArcGIS 3D Analyst*, Environmental Systems Research Institute, Inc., available at http://www.esri.com/software/arcgis/extensions/3danalyst/index.html (accessed 24 October 2012)

Gill, L., Kumar, V., Lange, E., Lerner, D., Morgan, E., Romano, D. and Shaw, E. (2010) 'An interactive visual decision support tool for sustainable urban river corridor management'. In: Swayne, D.A., Yang, W., Voinov, A.A., Rizzoli, A. and Filatova, T. (eds). *Proceedings of iEMSs 2010*, Ottawa, Canada, pp. 1431–8

Gothein, M.L. (1966) *A History of Garden Art*, W. P. Wright (ed.), New York: Hacker Art Books

Hehl-Lange, S. (2001) 'Structural elements of the visual landscape and their ecological functions'. *Landscape and Urban Planning*, 54(1–4), 107–15

Herwig, A. and Paar, P. (2002) 'Game engines: tools for landscape visualization and planning'. In Buhmann, E., Nothelfer, U. and Pietsch, M. (eds) *Trends in GIS and Virtualization in Environmental Planning and Design*. Heidelberg: Wichmann, pp. 161–72

Hoinkes, R. and Lange, E. (1995) '3D for free: Toolkit expands visual dimensions in GIS'. *GIS World*, 8(7), 54–56

Isaacs, J., Falconer, R. and Blackwood, D. (2008) 'A unique approach to visualising sustainability in the built environment'. In *Proceedings of the 2008 International Conference Visualisation*, Los Alamitos, CA: IEEE Computer Society Press, pp. 3–10

Kibria, M.S., Zlatanova, S., Itard, L. and Dorst, M. (2009) 'GeoVEs as tools to communicate in urban projects: requirements for functionality and visualisation'. In Lee, J. and Zlatanova, S. (eds) *3D Geo-information Sciences* (Lecture Notes in Geo-information and Cartography), Berlin: Springer, pp. 379–95

Lange, E. (1990) 'Vista management in Acadia National Park'. *Landscape and Urban Planning*, 19(4), 353–76

——(1994) 'Integration of computerized visual simulation and visual assessment in environmental planning'. *Landscape and Urban Planning*, 30(1–2), 99–112

——(2001) 'The limits of realism: perceptions of virtual landscapes'. *Landscape and Urban Planning*, 54(1–4), 163–82

——(2011) '99 volumes later: We can visualise. Now what?'. *Landscape and Urban Planning*, 100(4), 403–6

——and Hehl-Lange, S. (2010) 'Citizen participation in the conservation and use of rural landscapes in Britain: the Alport Valley case study'. *Landscape and Ecological Engineering*, 7, 223–30

Layar, B.V. (2012) 'Layar Reality Browser: Augmented Reality Software (IPhone application). Vers. 6.2.1.' Available from http://itunes.apple.com/gb/app/layar-reality-browser-augmented/id334404207?mt=8 (accessed 24 October 2012)

Laycock, R.G. and Day, A.M. (2003) 'Rapid generation of urban models'. *Computers and Graphics*, 27(3), pp. 423–33

Lesage, P.-L. and Visvalingam, M. (2002) 'Towards sketch-based exploration of terrain'. *Computers and Graphics*, 26(2), 309–28

Lynch, K. and Hack, G. (1984) *Site Planning*, 3rd edn, Cambridge, MA: MIT Press

Morgan, E., Gill, L., Lange, E. and Romano, D. (2009) 'Rapid prototyping of urban river corridors using 3d interactive, real-time graphics'. In Buhmann, E. Kieferle, J., Pietsch, M. and Kretzler, E. (eds) *Proceedings of Digital Landscape Architecture 2009*, Malta: Anhalt University of Applied Sciences, pp. 198–205

Morgan, E., Gill, L. Lange, E. and Dallimer, M. (2012) 'Integrating bird survey data into real-time 3D visual and aural simulations'. In Buhmann, E., Pietsch, M. and Ervin, S. (eds) *Digital Landscape Architecture 2012*, Berlin: Wichmann, pp. 492–8

Müller, P., Wonka, P., Haegler, S., Ulmer, A. and Van Gool, L., (2006) 'Procedural modeling of buildings'. *ACM Transactions on Graphics (TOG) - Proceedings of ACM SIGGRAPH 2006,* 25(3) New York: ACM, pp. 614–23

Nienhaus, M. (2005) *Real-Time Non-Photorealistic Rendering Techniques for Illustrating 3D Scenes and Their Dynamics*. Potsdam: University of Potsdam

Paar, P. (2006) 'Landscape visualizations: applications and requirements of 3D visualization software for environmental planning'. *Computers, Environment and Urban Systems*, 30(6), 815–39

Perrin, L., Beauvais, N. and Puppo, M. (2001) 'Procedural landscape modeling with geographic information: the IMAGIS approach'. *Landscape and Urban Planning*, 54(1–4), 33–47

Repton, H. (1980 [1803]) *Observations on the Theory and Practice of Landscape Gardening: Including some Remarks on Grecian and Gothic Architecture*. Oxford: Phaidon

Ribarsky, W., Wasilewski, T. and Faust, N. (2002) 'From urban terrain models to visible cities'. *IEEE Computer Graphics and Applications*, 22(4), 10–15

Schroth, O., (2007) 'From Information to Participation – Interactive Landscape Visualization as a Tool for Collaborative Planning'. Dissertation No. 17409. ETH Zürich

Steinitz, C. (1990) 'A framework for theory applicable to the education of landscape architects (and other environmental design professionals)'. *Landscape Journal*, 9(2), 136–43

Tufte, E.R. (1997). *Visual Explanations: Images and Quantities, Evidence and Narrative*, Cheshire, CT: Graphics Press

Wonka, P., Wimmer, M., Sillion, F. and Ribarsky, W. (2003) 'Instant architecture'. *ACM Transactions on Graphics (TOG) - Proceedings of ACM SIGGRAPH 2003,* 22(3), New York: ACM Press, pp. 669–77