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Guidance for crystal ball gazers: developing a code of ethics for landscape visualization

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Abstract

Computer visualization of landscapes in three or four dimensions constitutes a "crystal ball" capable of showing us views into the future. This paper discusses the risks of the growing but unstructured use of these landscape visualizations as a popular decision-making and public communications tool in planning. The author argues that we need to establish a framework for guidance and supporting resources for the use of landscape visualization, including accepted procedures, training, appropriate databases, and a communication network for users. In particular, it is argued that the preparers of visualizations — whom we can think of as the "crystal ball gazers" who conjure up and interpret the imagery — need to be governed by a code of ethics for defensible landscape visualization.

Drawing on research on visualization effectiveness and validity, as well as anecdotal evidence from professional practice, the paper identifies potential problems associated with emerging visualization technologies, and reviews the needs for, progress toward, and potential benefits of a support infrastructure for visualization preparers and presenters. A framework for guidance and support of visualization practitioners is proposed, in the hope of improving the chances of ethical practice and scientific validity in the use of these systems. Pending more comprehensive findings from the considerable body of research which is needed on this subject, an interim code of ethics is presented, for consideration, testing, and amendment by other researchers and users. It is suggested that such a code include broad principles and guidance on ethical conduct in producing visualizations, presenting them to viewers, and analysing responses to them from users as feedback.

Implications for future research and practice are provided, with an emphasis on the urgent need for researchers to monitor and evaluate the use and influence of landscape visualizations in practice.

Keywords: Visualization; Visual simulation; Ethics; Computer graphics; Simulation validity; 3D modelling; Decision support; Virtual reality

1. Introduction

Computer visualization of landscapes in three or four dimensions constitutes a "crystal ball" capable of showing us views of the future. The quickening pace of technology, driven primarily by the military and entertainment sectors, promises continuous "improvement" in visualization capabilities: a faster, more realistic, more sophisticated crystal ball (Sheppard, 1999a). However, in a planning and decision-making context, do we know how to use these incredibly powerful and sophisticated tools appropriately? Are further improvements in technology as urgently needed as further improvements in our knowledge and control of how such systems are used?

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This paper argues that we need to establish a framework for guidance and supporting resources for the use of landscape visualization, including accepted procedures, training, appropriate databases, and a communication network for users. In particular, it is argued that the preparers of visualizations — whom we can think of as the "crystal ball gazers" who conjure up and interpret the imagery — need to be governed by a code of ethics for defensible landscape visualization.

The scope of the paper addresses visual simulation or landscape visualization, as used in decision-support for environmental planning and resource management. This corresponds to the experiential type of visual simulation as defined by Appleyard (1977), with higher levels of "realism" which permit judgements of perceived qualities based in part on affective reactions in observers. This is in contrast to the conceptual type of simulation which is intended to enhance understanding of structural organisation or processes in the environment.

This paper does not focus on the crystal ball itself: the visualization technology. There is an expanding literature on the limitations and resulting validity of visualization technologies, exploring dimensions such as image (colour) resolution (Bishop and Leahy, 1989) and colour accuracy (Daniel et al., 1997). Appropriate design specifications for landscape visualization techniques have been suggested by this author elsewhere (Sheppard, 1999b). Rather, this paper addresses the many other factors arising from the process of simulation preparation which contribute to the validity, reliability, and effectiveness of landscape visualizations used in practice, but which do not seem to receive as much attention. Examples include the influence of client pressure, poorly understood modelling software, and limited landscape data.

Section 2 of this paper addresses fundamental questions about the need for guidance in landscape visualization, and the risks of making planning decisions without such guidance. Section 3 discusses desired characteristics of a support infrastructure for "crystal ball gazers", including a code of ethics. Implications for research and practice are discussed in Section 4.

The paper draws on a variety of sources, including published literature on visualization, recent research findings, the author's professional experiences, and anecdotal evidence (including personal communications with practitioners) where other information is sorely lacking. Illustrations of the use of landscape visualization are drawn primarily from applications to forested landscapes.

2. Why do we need guidance for "crystal ball" gazers?

2.1. Trends in use of the "crystal ball" in planning

The history of use of visualization has been succinctly described by Ervin and Hasbrouck (1999). Although, some forms of visualizing real or imagined landscapes have been with us for centuries (Bosselmann, 1998), there has been a substantial increase in the types and usage of visual simulation in professional practice in recent decades. Appleyard (1977) described many of these forms as applied to landscape and urban planning, but since then, there has been a still more dramatic increase in the range and sophistication of computer-based visualization techniques (McGaughey, 1998; Uusitalo et al., 1997; Sheppard, 1999c).

Over the last 30 years, various ways to produce highly realistic landscape visualizations have emerged. Craik et al. (1980) documented the convincing realism of detailed scale models. Sheppard (1986) described techniques of achieving photorealism by various approaches including retouching photographs manually. Orland (1988) discussed the potential benefits of manipulating photographs or video by image-processing. More recently, 3D and hybrid 2D/3D visualization programmes such as 3D Studio Max and World Construction Set permit 3D modelling of landscapes with a high degree of pictorial realism (Fig. 1), from multiple viewpoints or animation paths (Sheppard, 1999d). Historically, these techniques have required considerable skill and experience if convincing realistic visualizations were to result, and hence, have remained largely within the domain of a relatively small number of experts.

The evolution in visualization technology has been accompanied by an increase in the general level of interest in visualization in many fields, as witnessed by the popularity of books by Edward Tufte (e.g. Tufte, 1990). The trend towards "high-tech special effects" in the film industry and virtual reality in the

Fig. 1. Example of a highly realistic, 3D-modelled forest landscape image, prepared with World Construction Set. (Credit: Jon Salter, Centre for Advanced Landscape Planning, UBC Faculty of Forestry. Courtesy of UBC Research Forest).

entertainment sector has been followed by increasing reliance on visual information in many areas of corporate business. The number of people likely to use computer visualization, and the number of people demanding its use, appears to be increasing steadily, although it is difficult to find measurements of this growth. It is perhaps surprising how seldom in the past that visual simulations have been routinely required by government agencies involved in land and resource planning decisions (Lange, 1994), as indicated by the limited number of policies requiring simulation found by this author (Sheppard, 1989). However, even the most advanced visualization systems appear now to becoming much more common. In British Columbia, for example, many of the visual impact assessments conducted for timber harvesting in more visually sensitive areas are now accompanied by images created in programs such as World Construction Set, which are seen by the preparers as being more defensible and accurate than the previous methods (Bunning, 1999).

This trend seems likely to continue gathering momentum. Childhoods dominated by video arcades or Nintendo will furnish an entire generation of users not only trained in computing but familiar with and expectant of interactive, virtual reality capabilities. As with the evolution of GIS to more ‘‘user-friendly’’ software versions such as ArcView and MapInfo, and the inclusion of ‘‘paint’’ programs with standard PC software, we can also expect visualization programs to become simpler to use and more available for would-be preparers. It is of particular relevance that there seems among both young and old to be a general hunger for (and gratification received from) more realistic landscape imagery, as though this was automatically better than the imagery from less high-tech media.

Therefore, the demand for visualizations, the number of users able on their own to ‘‘figure out’’ how to prepare them, and the consequent volume of realistic visualizations used in planning decisions, can be expected to grow exponentially.

2.2. The argument for guidance of ‘‘crystal ball gazers’’

If many more people learn how to prepare landscape visualizations, if producing sophisticated realistic imagery becomes more straightforward, and if decision-makers become used to seeing them, why worry about how the visualizations are produced? Would not the results pop out automatically with the push of a few buttons? Are not computer-based visualizations already data-driven?

While the potential benefits of landscape visualization in planning are clearly substantial (Orland, 1988; Sheppard, 1989; Ervin and Hasbrouck, 1999), those who would argue against a laissez-faire attitude to the use of landscape visualization recognize that faith in the technology, or in the mastery of that technology, does not guarantee the appropriate outcome. The complexity of representing in two or three dimensions the visual totality of a future environment inevitably means that the appearance of the final product can depend just as much on how the visualization process is conducted, as upon the technology being used (Sheppard, 1989). There are many potential influences on the visualizations used in decision-making, which go well beyond the choice of software program or dataset to be used.

By way of an analogy, the car is a revolutionary modern technology with a wide range of performance, speed, sophistication, and price. However, both an old Volkswagen and a new Rolls Royce will get passengers to their destination, provide freedom and convenience, and enable enjoyment through sightseeing; likewise, both kinds of cars can also kill people, pollute the air, and damage the environment, if driven inappropriately. Few would argue against speed restrictions, warning signs, driver training, driver's licenses, emission checks, or even the highway patrol.

The need for some form of support for preparers of landscape visualizations has now been expressed at several gatherings of leading landscape architectural practitioners and academics in the last few years. Most notably, workshops addressing this topic have been held in Las Vegas in 1991 (Orland, 1992), in St. Louis in 1997 (Orland, in this issue), at Lake Tahoe in 1997 (Strain and Sheppard, 1997), and most recently at the Our Visual Landscape Conference in Ascona, Switzerland (described elsewhere in this Issue).

Arguments for some sort of general guidance to "crystal ball gazers" revolve around the following issues:

- the power of landscape visualizations to affect planning decisions;
- the potential for misuse of visualizations (deliberate or otherwise) and the consequences of any misuse;
- inadequacies in our current abilities to identify, control or compensate for misuse of visualizations;
- the spin-off benefits of guidance to would-be users of visualization.

Before discussing these issues, it should be noted that one of the principal arguments against producing a code of ethics and support infrastructure for landscape visualization is that we lack much of the knowledge to prepare defensible guidelines for visualization preparers, especially in the area of sufficient realism for particular simulation purposes.

Nonetheless, this author argues that it is better to convey what we do know or suspect from the limited research findings available (e.g. Lange, 1999; Meitner and Daniel, 1997), supplemented by practical experience and common sense, than to sit back and do nothing. We can only evolve an effective code of ethics through experience in testing it.

2.2.1. The power of landscape visualization

The influence of visualizations on perceptions and decisions is widely acknowledged. The persuasive power of visualizations has not been lost on the entertainment, business, and advertising industries, where visual information is a huge growth area (Danahy and Hoinkes, 1999). The human reliance on visual information to absorb knowledge and our abilities to infer subtle distinctions from this source has been documented by countless authors: Appleyard (1976), for example, demonstrated people's ability to infer many details of socioeconomic condition from simple photographic images of a neighborhood. Daniel and Meitner (2000) cite several experimental studies which have demonstrated the power of visualizations "to affect attention, to alter interpretations of complex concepts and differentially to arouse positive and/or negative emotions" (p. 4). In research underway at the University of British Columbia, using qualitative and quantitative analysis of interview transcripts, we are documenting the power of photorealistic computer-generated visualizations (as compared with ArcView mapping) to stimulate enhanced communication of traditional knowledge and opinions on resource management alternatives within an aboriginal community. At a broader level, experience with presentation of visual simulations at community and agency meetings throughout North America over the last 20 years suggests to this author that the effect of landscape visualizations in raising unforeseen issues, changing opinions, eliciting strong reactions, or confirming previously unsubstantiated beliefs, is the rule rather than the exception in practice.

Interestingly, the volume of documented evidence in the scientific literature on the effect of visualizations on actual planning decisions is very small. This remains an enormous area of need in the research. The following statement, penned in 1987, applies almost as much today as it did then: ‘‘It is clear, in spite of the absolute dependency of designers on simulations as a means of communication, that very little is known about the communication effectiveness of these media’’ (Zube et al., 1987, p. 75); or, perhaps, it would be truer to say that the practitioners know quite well what the effectiveness of their own simulations is, and that is why they use them: it is just the scientific knowledge that is lacking.

Nonetheless, since we believe that landscape visualizations can influence people' emotions much more than the products of other visual technologies such as GIS maps, it remains an urgent priority to improve our understanding and to control the impact of visualizations in decision-making.

2.2.2. *Misuse of visualization*

If the power of visualizations to influence decisions is so great, then any variability or unreliability in the visualizations has the potential to mislead the viewer. Beyond the limitations and effects of the visualization media themselves (which are not the focus of this paper), there are several possible causes of variability in visualizations (both unintentional and intentional), and therefore of potential misuse. This section discusses some of these causes, as well as the potential consequences of misuse.

The inadequacy of data to populate the highly realistic visualization systems now becoming available is a fundamental concern (see Orland in this issue). In a forest landscape setting, for example, certain types of forest stand data related to timber volume and silvicultural characteristics may exist in mapped form for current conditions; however, data on visual attributes of the existing landscape, future 3D forest stand conditions, and visual attributes of future forest landscapes are not systematically available. In most cases, predictive simulations cannot be said to be data-driven: most of the data used in preparing realistic visualizations is existing data (e.g. timber inventory data, existing photographs, satellite imagery), and the use of current 3D predictive models (e.g. terrain, or geometric trees) can only assist, not drive the simulation. Inevitably, the preparer makes numerous choices on how the visualizations look. Valid and realistic visual models for project planning which are ‘‘capable of creating visual simulations directly from data about the impact, without the intervention of an expert operator’’ (Orland, 1994, p. 94), appear a long way off.

The mode of presentation is also very important. A single set of visualizations can be presented in very different ways: for example, in a live big-screen projection, a small colour illustration in an environmental report, or a grainy black-and-white newspaper article. Danahy (in this issue) describes the improved understanding of site conditions gained through immersive displays in design review (Fig. 2), as compared with smaller, narrower, static presentations. Again, the variability in effect of a visualization due to presentation mode introduces serious unanswered validity and reliability questions.

There are many other influences on the preparation of visualizations in the real world, including content choices, viewpoint location, and conditions of lighting, weather, and season. The context in which visualizations are produced can exert a profound effect on the nature of the visualizations used in practice. Preparers of visualizations often have budgets which are too small, and clients who are either unconvinced of the value of more simulations or wish to control their content. The author (Sheppard, 1999b) has described instances of clients withholding visualizations from public display because they may not favour the cause of their project. Most architects and landscape architects are trained to present their designs in the most favourable light. In a recent white paper promoting a new visualization program from the computer manufacturer Evans and Sutherland (1999), landscape visualization is described as ‘‘an incomparable tool for winning approval quickly or speeding the funding process for a proposed project’’ (p. 2). Where the preparer is uncomfortable with these pressures, there are no standards or professionally agreed procedures

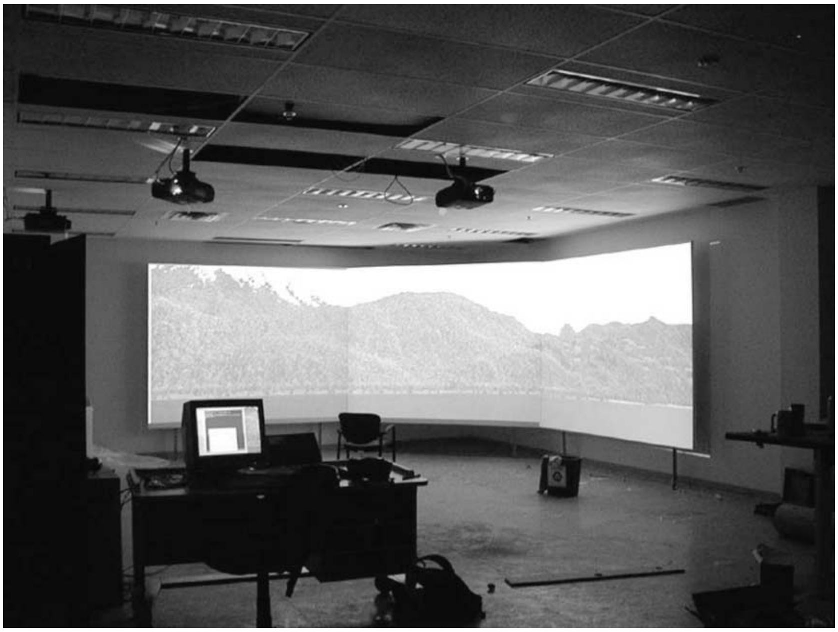

Fig. 2. The Immersion Lab at the Forest Sciences Centre, University of British Columbia, Vancouver, with three 8′ × 10′ screens in panoramic ''wrap-around'' configuration. (Credit: Duncan Cavens, Centre for Advanced Landscape Planning, UBC Faculty of Forestry).

to fall back on in negotiating with the client. Luymes (2000) concludes that simulations are rarely if ever value-neutral.

Even with the best intentions, any two preparers, using the same software and the same base-data, are likely to produce very different visualizations, due to the lack of visual landscape data and enormous range of perceptual variables to be simulated (see Fig. 3). With these levels of unreliability, together with media influences, we can agree with Daniel and Meitner (2000, p. 12): ''Environmental visualizations may be completely accurate with respect to their portrayal of relevant and accurately projected bi-physical conditions, but still produce perceptions, interpretations, and value judgements that are not consistent with those that would be produced by actual encounters with the environments represented''.

The potential consequence of such effects are poor decisions in planning, where unworthy projects are given planning approval, good designs are turned down, and planners and the public alike get that which they did not expect (Sheppard, 1989).

While the likelihood of visualization unreliability is high and there is much scepticism in the literature (e.g. McQuillan, 1998; Luymes, 2000; Sheppard, 1999a), the scientific evidence for the extent and consequences of misuse in practice is almost non-existent. A few researchers have tested levels of inaccuracy in experimental simulation images compared with the real landscapes (e.g. Sheppard, 1982; Watzek and Ellsworth, 1994), and some have found bias in responses to some media compared with those arising from the real landscape (e.g. Oh, 1994; Bergen et al., 1995; Wherrett, 1999). This indicates problems with at least some visualization media, though there has been insufficient research to establish comprehensive patterns or to tease apart the influence of technology, data, and the simulation process. Sheppard (1989) documents bias recorded in responses to approximately 30 built projects and the corresponding visual simulations actually used in the project decision-making process. However, there is little scientific documentation of the role of visualizations in actual planning decisions, and the influence of their inaccuracy or bias on decision-making. Clearly, however, practitioners share the academics' scepticism: in a 1994 survey of US Forest Service landscape architects, 60% of respondents identified ethics and

(a)

(b)

Fig. 3. One scene modelled in two different weather conditions, using World Construction Set. (Credit: John Lewis, Centre for Advanced Landscape Planning, UBC Faculty of Forestry. Courtesy of UBC Research Forest and Garten + Landschaft).

truthfulness as the most important policy issue relating to visual simulation (Palmer, 1994).

2.2.3. Current constraints on misuse of visualization

The fear of misleading visualizations could be allayed if there were adequate checks and balances on the system, to identify, control or compensate for such misuse. This section considers constraints on misuse currently in existence. These include constraints built into the visualization systems themselves, policy constraints set by agencies using visualizations, professional guidance and training for ''crystal ball gazers'', and monitoring or enforcement measures.

2.2.3.1. Visualization system constraints. Visualization system constraints potentially could include the inherent transparency of the visualization system itself, design specifications or safeguards built into the technique, and system-specific user guides. The last two of these are not addressed in depth here, except to say that visualization software manuals and procedures tend to focus largely on the mechanics of the process, not the principles.

The transparency of the medium in this context refers to the extent to which errors become self-evident under ordinary visual inspection, and the extent to which a viewer can retrace the steps followed in preparing the visualization. Luymes (2000) (1) and others have noted that the increasing sophistication of visualization methods increasingly masks the uncertainty and potential for misleading viewers; the degree of realism, the apparent basis in data, and the level of complexity itself may prevent viewers from understanding the limitations of the imagery shown. As Orland (1994, p. 85) puts it: "as a general rule, the greater the realism in the visualization, the weaker the demonstrable links to underlying resource data or projections" Luymes (2000) goes further to assert that the very realism itself breeds the expectation of accuracy, reliability, and authority of the preparer. As an example, in research we are conducting with a community in BC's Fraser Valley, most respondents remain unaware that images of existing conditions are actually a blend of photograph and modelled WCS imagery, even though they are intimately familiar with the portrayed landscape. Clearly, errors may not be easily detected in fully computer-modelled landscape images, and such visualizations are not self-regulating. In fact, there is now a seamless transition from modelled landscapes of pure fantasy to actual landscapes modelled with high accuracy, with the two being almost indistinguishable (see Fig. 4).

Having said that, there is also a healthy scepticism in many communities when simulations of various types are used. While this has not been systematically documented by researchers anywhere to the author's knowledge, public comments on many EIAs and planning approvals for projects do record numerous public criticisms of simulations used in decision-making (Sheppard, 1989), although these may focus more on preparer's motivations, image content, choice of viewpoint, and media slickness rather than on bias concealed by the level of apparent realism. The degree to which such public scepticism is acted upon or influences the decision is unknown.

2.2.3.2. Policy constraints. Some policy tools for regulating how visualizations are used in planning and decision-making do exist (Sheppard, 1989). Various agencies provide some guidance: for example, the BC Ministry of Forests (BCMoF) recommends the preparation of visual simulations for each design option being assessed, and provides some guidance on selecting appropriate visualization media (BCMoF, 1995); the California Energy Commission (CEC) requires that the most visually sensitive key observer points be represented by "before and after" visualizations (CEC, 1996); and the City of San Francisco's high-rise approval process stipulates where photorealistic simulations should be taken from (City of San Francisco, 1987). It is not clear, however, whether there is any consistency

Fig. 4. Example of a highly "realistic" but totally synthesized fantasy landscape. (Credit: Paul Fearing, Imager Lab, UBC Department of Computer Science).

between these policies, or to where agencies turn in order to develop or update such policies. In this authors experience, most agencies charged with planning decisions do not have any such policies.

Legal instruments which regulate environmental assessment procedures, such as NEPA and various state laws in the USA, may prescribe the text content and performance standards for environmental impact assessments (EIAs), but generally set no standards for use of visual simulations, even though these may be the one thing the lay-reader can readily understand.

2.2.4. *Professional guidance and training*

A professional support infrastructure for preparers of landscape visualizations, as discussed at the "Data Visualization Techniques in Environmental Management" workshop (Orland, 1992), might include a code of practice, procedures and guidelines, data provision, training, acquisition of experience/apprenticeship, and a means of disseminating information. Does an adequate infrastructure exist which offers these kinds of support to "crystal-ball gazers"?

Clearly, the answer is "no". Agreed data standards or procedures for collecting site-specific information for visualization have not been developed. As Daniel (1992) says: "There is a substantial foundation of formal studies and theory to guide the processes of measurement and statistics, which translates states of the world into data. However, the inverse process by which data representations are translated into environmental images...is essentially unexplored" (p. 262).

Most people with visualization experience are self-taught and have obtained their skills "on the job"; in the 1996 status report on computing skills and training in landscape architecture in the USA, Palmer (1997) found that two-thirds of the survey respondents gained their computer skills by teaching themselves. The difficulty of obtaining good training was the third highest problem reported by these respondents. It typically takes years of training and experience to learn how to integrate abstract data from diverse sources into accurate (as distinct from realistic) representations (Daniel, 1992). There are still very few professional or academic courses in applied landscape visualization, and still fewer that focus on principles rather than technique.

General procedures and guidelines do exist (e.g. US Bureau of Land Management, 1980; Sheppard, 1886; Sheppard, 1989; USDA Natural Resources Conservation Service, 1995), but most are somewhat outdated and/or focussed on specific landscape situations. Also, they appear generally not to be well known to or used by the average practitioner. Various procedures for visual impact assessment include some limited guidance for practitioners on visual simulation (e.g. UK IEA/LI, 1995; BCMoF, 1995), but tend to focus mostly on selection of appropriate media.

The slow pace at which a support infrastructure for visualization evolves (relative to the technology) is demonstrated by the progress made since the 1991 workshop (Orland, 1992). As Table 1 shows, there has been very little advance in the landscape visualization sector in most of the items predicted for the period to date. Where progress has been made, it has focused on technological development (in both commercial and academic systems), and any substantive information exchange has been largely between academics already active in the field. Collaborative links with the professions, government, and industry have been sporadic and limited at best. The development and dissemination to the US Forest Service of SMART FOREST II (Orland, 1997), a sophisticated and flexible research-based visualization programme for forestry, is a rare exception which merits thorough evaluation in practice.

It is interesting to note also that few of the recommendations in 1991 called explicitly for codes of practice, common standards, monitoring of use (versus needs) in practice, and other programs to establish the reliability, accuracy, and impacts of techniques used in practice. Individual authors such as Chenoweth (1991), however, have called for such programs.

2.2.4.1. Monitoring and enforcement. In theory, it would be possible to monitor the accuracy and reliability of visualizations, with penalties for inaccurate or deliberately biased simulations. To the author's knowledge, with the exception of a few site-specific programs to evaluate the accuracy of simulations in comparison with post-construction landscape conditions, comprehensive monitoring programs for visualizations at the time of use are rare, and no enforcement/penalty programs have been developed. Chenoweth (1991) has argued for

Table 1
Achievement of expectations for landscape visualization from the 1991 workshop on data visualization techniques in environmental management

Workshop expectations for visualization[a]	Achieved
3–5 year expectations (by 1996)	
Establish professional organisation	No
Establish professional journal	No
Develop curriculum	No
Establish program to accelerate declassification of technology	Unknown
Various system developments in software/hardware/networking development	Underway
10 year expectations (by 2001)	
Develop accredited education and training programs	No
Access global data streams	Yes (somewhat)
Develop real-time data collection capabilities	Underway
Monitor user needs	No
Monitor technology	Yes (informally)
Other recommendations	
Needs assessment (user-awareness programs, pilot projects, rapid prototyping)	Mostly no
Cooperative resource pool/support network (e.g. regional centres for learning and training, expertise exchange, workshops)	Mostly no
Research, development, and applications program	Partially

[a] Source: landscape and urban planning, 21 (special issue on data visualization for environmental management).

the use of visualizations as negotiated legal documents or contracts between project applicants and regulators, as well as calling for basic documentation of the use of visualizations in actual decision-making. Decker (1994) reviewed ways in which realistic visualizations could be labelled as such and preparers could be identified by a unique symbol or signature, although no such trend has emerged to the author's knowledge.

Overall, the field of landscape visualization seems to represent the ''wild west'' of planning procedures: the inexperienced, slipshod, or crooked crystal-ball gazer would appear to have little to fear.

2.2.5. Practical benefits of a support infrastructure for visualization

If a support infrastructure to guide and monitor the use of landscape visualizations could be mounted, what benefits might accrue? Clearly, if misuse can be reduced, then better land use decisions may result, or at least some bad decisions (as described above) may be avoided. Also, a solid source of up-to-date advice for logistical issues such as which system to buy, how much realism or immersion is needed, etc. would have great practical usefulness.

However, it is also worth considering the costs of having no recognized professional framework or standards for preparing and using landscape visualizations, as a measure of the indirect but tangible benefits of establishing such a support infrastructure.

Where visualizations are shown to be misleading, as can happen after construction of the project, the resulting public dismay can bring both the preparer and the technique into disrepute. Anecdotal evidence reported from several past projects in California and BC suggests such consequences are not uncommon. In fact, as landscape visualizations become more commonplace in public decision-making, there is an increasing likelihood of debate over their veracity, and of litigation resulting from differences between the visualizations and the built designs. Chenoweth (1991) raises real concerns over the liability of practitioners as visualizations assume the role of a legal contract. On the other hand, this author (Sheppard, 1989) documented projects where designs and other landscape conditions changed significantly after the use of visualizations in the project approval process. In this situation, without recognized procedures for documenting the visualization process and demonstrating conformance with a professional code of practice, practitioners are vulnerable to unfair accusations of bias and error. However, the actual incidence of bias and error may in fact already be unacceptably high.

A code of ethics would establish clear guidelines on appropriate approaches to preparing and presenting visualizations of future landscapes, and would provide a means to determine whether a given visual representation/process has met the recommended procedures or minimum standards of the profession (Bedwell, 1997). At the same time, the code would provide a defensible basis for informing clients, approval agencies, and the public that no visualization can be completely accurate or fully representative of a built project (Palmer, 1999).

Lastly, there are potentially strategic benefits to the profession(s) which establish leadership in the field, assuring a highly visible role on major projects in the public eye. In some areas, the author has observed that the engineering profession (and not the landscape architects who actually have graphics training) appears to dominate the applied visualization field. On major transportation projects such as the San Francisco Bay Bridge design competition, it is understood that none of the high-tech visualizations employed (Fig. 5) were produced by landscape architecture or planning firms (MTC, undated).

3. What should a support infrastructure for visualization include?

Possible components of a support infrastructure for landscape visualization have been described in Table 1 above, based on Orland's research development application plan (Orland, 1992). A revised framework for these kinds of support for users of visualizations is presented here, comprising.

- General principles and responsibilities laid down in a code of ethics.
- Best practice guidelines, standards, and specific procedures to assist preparers directly in their visualization work.
- Professional support networks and institutions.

The focus here will be placed on the first of these components.

3.1. General principles and an interim code of ethics

Perhaps the simplest part of a support infrastructure to establish will be the general principles, since these represent "motherhood" statements which most would find it hard to argue with, and there is considerable consensus in the research literature. It is of

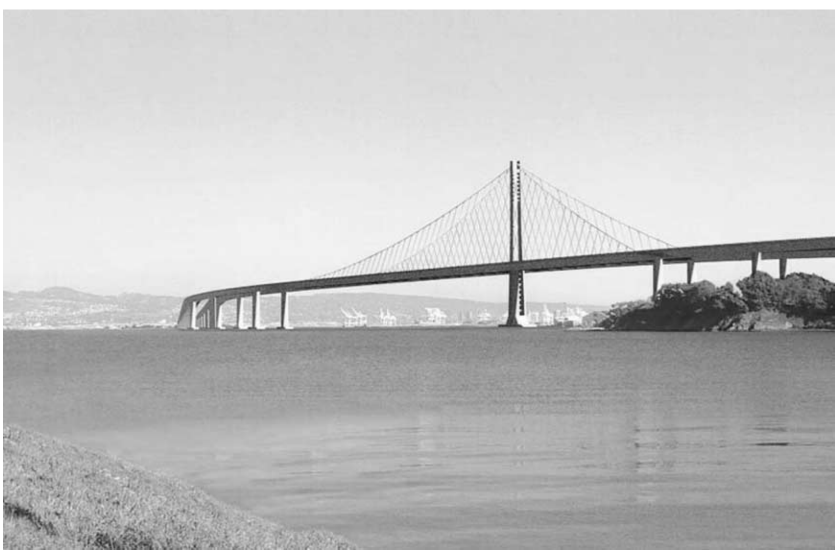

Fig. 5. Example of a 3D-modelled visualization of the proposed Bay Bridge replacement structure in San Francisco. (Courtesy of Metropolitan Transportation Commission, Oakland, CA).

course much easier to say what we need than to say how to achieve it or actually to provide it.

The following discussion draws on a preliminary review of selected precedents for codes of ethics or professional conduct in allied fields, including photojournalism (Kenney, 1991; Anonymous, 1999) and planning (PIBC, 1999).

Ultimately, the purpose of landscape visualizations in planning is to contribute to better decisions. A good decision might be defined as one which would not be changed with hindsight. Without the luxury of hindsight, aspects of a better planning decision might include a broadly-based decision which considers all key consequences (short term and long term), is based on all the relevant knowledge available at the time, includes collaborative input from the full range of affected parties, weighs alternatives, minimizes and/or discloses uncertainties, and is neutral within the range of competing interests. In this context, landscape visualizations need to convey information that cannot be readily conveyed by other means, and thus validate or modify the messages from these other information sources: their role is therefore one of illustrating holistically a range of implications which can only be gleaned in pieces through other media, and specifically to provide the means for both an emotional (affective) response to proposed future environments and an analytical assessment of expected aesthetic changes.

In order to fulfil this role, it has been suggested that landscape visualizations need to achieve three fundamental objectives (Sheppard, 1989):

- convey understanding of the proposed project;
- demonstrate credibility of the visualization itself;
- avoid bias in responses to the proposed project.

Understanding and credibility depend in large part on communicating effectively to the intended audience. Various authors agree on the overriding importance of assuring validity and minimizing or avoiding bias, by achieving what has been termed response equivalence: the ability to stimulate responses which are similar to those that would be obtained with views of the real scene (Appleyard, 1977). Daniel (1992) has defined it as follows: "Data visualizations are sufficient to the extent that adding detail, higher resolution, color fidelity, animation or other features does not improve the match between representation-based and direct response" (p. 263). This is often thought of as a one-to-one correspondence in response to a specific scene and a specific visualization image, but in fact we should be thinking of a range of responses to the real project, matched by a range of visualizations, views, and supporting information which yields similar cumulative reactions. Zube et al. (1987), describing a research project on the Niagara Falls, have demonstrated the importance of providing non-visual information in conjunction with visualizations in order to obtain valid responses to project-specific questions.

General principles for project level landscape visualization which support the goal of response equivalence as well as acceptability to the audience, have been proposed by Sheppard (1989), as follows:

- *Accuracy*: visualizations should simulate the actual or expected appearance of the landscape (at least for those landscape factors being judged).
- *Representativeness*: visualizations should represent typical or important views/conditions of the landscape.
- *Visual clarity*: the details, components, and overall content of the visualization should be clearly communicated.
- *Interest*: the visualization should engage and hold the interest of the audience (although perhaps with current technology we should be more concerned with over-stimulation and media intoxication: what McQuillan (1998) refers to as the "wow-effect").
- *Legitimacy*: the visualization should be defensible and its level of accuracy demonstrable (see discussion of transparency above).

Despite the rapid evolution of visualization technology over the last decade, these principles would appear still to apply.

In particular, many authors cite the importance of accuracy and related concepts of reliability, fidelity or truthfulness in minimizing bias. Palmer et al. (1995), for example, refer to ecological validity, whereby it can be assured that the environments depicted are ecologically feasible, as well as to a more comprehensive criterion of image veracity. This author was unable to demonstrate a strong relationship between accuracy and bias in the approximately 30 simulations examined after construction of the corresponding projects (Sheppard, 1982). However, subsequent controlled experiments have demonstrated increasing bias with some forms of inaccuracy (e.g. Bishop and Leahy, 1989; Bergen et al., 1995; Meitner and Daniel, 1997), and there is a general indication that the more realistic the image, and the more affective or qualitative are the important response dimensions, the higher the accuracy should be (Daniel and Meitner, 1997). Obviously, it is impossible to assure complete accuracy when the actual state of the future environment cannot be precisely predicted. However, there is a strong precautionary principle reflected in the bulk of the literature, to the effect that, while accuracy may not be absolute or enough by itself to assure validity, there is danger in permitting major inaccuracies in visualization content (McGaughey, 1998; Sheppard, 1999d).

There may be exceptions to this where it can be shown that experts make more valid judgements from inaccurate images than non-experts, as demonstrated by Daniel et al. (1997) with forest health evaluations using false colour images. This underscores the need to fit the visualizations to the audience and type of decision. Zube et al. (1987) point out the importance of the stage of project development in determining the appropriate type of visualizations to use. Palmer et al. (1995) have suggested that professionals need a rating system for "simulation veracity", fitted to four basic levels of visual simulation (conceptual, illustrative, similar, and probable) which are tied to the stage of project development and approval. They recommend that landscape visualizations in the two later stages should be certifiable as accurate.

Current trends towards more participatory land and resource planning, together with advances in communication technology, can be translated into some additional principles for the use of landscape visualization systems (Sheppard, 1999d). These considerations include the desirability of more access to visualization products over channels such as the web and cable TV; more choices of views, conditions, and alternatives visualized; and more involvement of the public in determining how the visualizations are prepared and interrogating them when complete. Pitt and Nassauer (1992) advocate a participatory approach whereby observers can select viewpoints themselves and even modify the visualization images interactively. Sheppard (1999d) describes the use of interactive (Quick Time VR) visualization in combination with other media for public information programs on one proposed project, and Meitner and Daniel (1997) have found good response equivalence with such techniques compared with on-site views. Rafaeli (1988) in his useful discussion of definitions of interactivity provides potential criteria for appropriate participatory visualization, including degree of user control and amount of feedback enabled.

Of course there are limits to what is feasible and affordable, requiring the desired conditions of a visualisation to be balanced against practical constraints. Perkins (1992) defines a simulation image as good enough if it "has a high degree of perceived realism, conveys maximum quality, contains enough data, yet is efficient in terms of equipment costs, storage and management" (p. 266). There is much work to do to identify thresholds of acceptability in achieving this balancing act, for example in defining adequate levels of realism, accuracy, etc. for specific types of decisions in specific types of landscapes.

Based on the preceding review, the statements provided in Table 2 are suggested for consideration as a preliminary or interim code of ethics for the current stage of technology, until research findings provide more comprehensive knowledge. It is hoped that the proposed code of ethics can be viewed as a working draft, to be criticized, reworked, tested in practice, supplemented to fit the needs of the profession, and ultimately validated through empirical research.

3.2. Guidelines, standards, and procedures for preparation and presentation of visualizations

An in-depth discussion of possible guidelines and procedures for landscape visualization is beyond the scope of this paper. However, we can assume that these are harder to define and support than general principles, in part because we have such gaping holes in our knowledge on specific influences on landscape decision-making. While some guidelines may be widely agreed upon already, such as avoidance of telephoto lenses (BCMoF, 1995), many more remain to be determined.

It seems logical that any such procedures should be structured around a general understanding of the full simulation process, and could tier off items defined in the code of ethics, as a basis for improving overall quality and effectiveness of visualizations. The typical landscape visualization process has been outlined

Table 2
Proposed interim code of ethics for landscape visualization

Purpose of landscape visualization
Professional preparers and presenters of landscape visualizations are responsible for promoting full understanding of proposed landscape changes; providing an honest and neutral visual representation of the expected landscape, by seeking to avoid bias in responses (as compared with responses to the actual project); and demonstrating the legitimacy of the visualization process
General principles
Preparers and presenters of landscape visualizations will adhere to the following general principles
Accuracy: realistic visualizations should simulate the actual or expected appearance of the landscape as closely as possible (at least for those aspects of the landscape being considered)
Representativeness: visualizations should represent the typical or important range of views, conditions, and time-frames in the landscape which would be experienced with the actual project, and provide viewers with choice of viewing conditions
Visual clarity: the details, components, and overall content of the visualization should be clearly communicated
Interest: the visualization should engage and hold the interest of the audience, without seeking to entertain or "dazzle" the audience
Legitimacy: the visualization should be defensible through making the simulation process and assumptions transparent to the viewer, and by clearly describing the expected level of accuracy and uncertainty
Access: to visual information: visualizations which are consistent with the above principles should be made readily accessible to the public via a variety of formats and communication channels
Code of ethical conduct
The use of landscape visualizations should be appropriate to the stage of development of project under consideration, to the landscape being shown, to the types of decisions being made, to the audience observing the visualizations, to the setting in which the presentation is being made, and to the experience level of the preparer. Within this context, preparers and presenters of landscape visualization will:
Demonstrate an appropriate level of qualifications and experience
Use the appropriate visualization system(s) and media for the purpose
Choose the appropriate level of realism
Identify, collect, and document supporting visual data available for or used in the visualization process; conduct an on-site visual analysis to determine important issues and views
Seek community input on viewpoints and landscape issues to address in the visualizations
Estimate and disclose the expected degree of error and uncertainty
Use more than one appropriate presentation mode and means of access for the affected public
Provide the viewer with a reasonable choice of viewpoints, view directions, view angles, viewing conditions, and timeframes appropriate to the area being visualized
Present important non-visual information at the same time as the visual presentation
Avoid the use or the appearance of "sales" techniques or special effects
Avoid seeking a particular response from the audience
Provide information describing how the visualization process was conducted and key assumptions/decisions taken
Record responses to visualizations as feedback for future efforts
Conduct post-construction evaluations to document accuracy of visualizations or changes in project design/construction/use

previously (Sheppard, 1989, 1999a). Guidelines and procedures should encompass not only the production of visualizations, but also their presentation to viewers and the documentation of viewer responses to them, as a vital feedback loop. Specific guidance may need to be developed by type and stage of project, type of landscape setting, visualization media, and other key variables affecting viewer response.

3.3. Professional support networks and institutions

Orland (1992) has described the need for a support network providing facilities, expertise, training, and data sharing between environmental and natural resource agencies using visualizations. Elements of this support infrastructure, as mentioned above, might include data standards and sources, information dissemination methods, public awareness building, and curriculum development.

This discussion is limited to two broad points. Firstly, preparers of landscape visualizations with powers to influence the viewers' emotions need to be trained not only in how to produce simulations, but also in how people respond to realistic landscape images. In other words, they need a solid background in aesthetics and human perception; most would-be preparers of visualizations currently have little scientifically-based knowledge on how people react to certain image content or media effects. This is therefore a tall order if the preparers come from diverse disciplines with no previous design or environmental psychology background.

The second related point is that one or more organisations need to endorse, champion, and enforce emerging codes of practice and standards if they are to be effective. Palmer et al. (1995) have suggested that some landscape visualizations should be certifiable, whereby professional skills and expert knowledge would be required and the preparer would assume liability for their accuracy. As pointed out above, if a profession such as landscape architecture were firmly to grasp this two-edged sword, it might find its standing considerably enhanced by the increasingly influential role of its members in the project decision-making process.

4. Discussion and conclusions

4.1. Implications for future research

Without attempting a comprehensive agenda for future research on landscape visualization, it is perhaps worthwhile to structure the research needs highlighted by the preceding discussion. Overall, much more research on the use of visualizations in real-world practice is needed. The author suggests the following hierarchy of research questions, in the context of monitoring use of visualizations in practice.

- Effectiveness of visualizations in communicating information.
- Effect of visualizations on perceptual responses.
- Effect of visualizations on observer behavior (projected).
- Effect of visualizations on resource management decisions made.

In addition to research needs comparing and validating simulation media, there is an urgent need to test experimentally the effect (alone and in combination) of the following variables:

- different visualization presentation modes (e.g. degree of animation and interactivity);
- different visualization content (e.g. long-term temporal stages, and visual data input options);
- different perceptual/decision-making questions/contexts.

4.2. Implications for practice

Dissemination of an agreed code of ethics and supporting guidelines would be expected to yield some of the benefits described earlier in the paper. However, considerable reluctance to adopt such policies can be expected from private developers and project applicants, who may not wish to have their traditional simulation approaches taken out of their control. Government agencies might be expected to endorse a new code of ethics, as a guide to reduce the scope of their own discretion in areas about which they may not feel comfortable.

Strategic questions which require considerable debate include.

- The extent to which experts (versus any would-be simulation preparer) are required to conduct or review visualizations.
- Who is best suited to prepare and present the visualizations: the designer, the applicant or their consultant, the regulator or their consultant, or some sort of independent body?
- What level of certification or standards is necessary or desirable?
- Which institutions and professions should take on this challenge?
- How can effective training programs (including training in ethics, landscape analysis, and aesthetic response to landscape imagery) be established?

From a practical standpoint, any such guidance would be helpful in the coming wave of visualization need assessments and implementation studies, which will be sponsored by companies and government agencies seeking to access the new technologies.

4.3. Conclusions

We have already crossed the principal threshold into 3D-modelled realism in landscape visualizations: further improvements are needed in the support system to guide the use of these powerful tools. There is a strong argument to be made that what we most need is not new technology, but more research and training on the methods we already have. The author concludes that we must build the knowledge/guidance systems to go with the new techniques, and both support and constrain the crystal-ball gazers.

We need to define and apply our principles for appropriate and effective visualization, obtain feedback on emerging codes of ethics, track the use and effectiveness of the visualizations we use, and exercise continual vigilance and self-criticism, if we are to evolve the appropriate support infrastructure for landscape visualization in planning.

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