Using Visualization for the Evaluation of Safety and Aesthetics Conflicts in Urban Parks

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1 Introduction

Urban parks are a vital and essential component of our landscape. Nevertheless, in some cases, historical parks are not used to their full potential. The problem of underused public parks is currently associated with the sense of fear and with the question of personal safety of visitors. Thus this research investigates some factors, which affect the user's perception of safety and of aesthetic, on behalf of the visual stimuli that are depicting landscape dynamics in urban parks. The aim of this study is to investigate the relation and the possible conflicts between personal safety and aesthetics for different conditions of "visual impermeability" (JORGENSEN 2002). The 3D visualizations show dynamics over time, in order to consider if these changes influence the evaluation of safety and aesthetics as expressed by the observers. The use of 3D visualization is already widespread for large-scale landscapes, such as forest and agricultural areas, but the present research explores an urban-scale object, the historical park, represented and analyzed at a very detailed scale. It is believed that the value of a park must be related not only to its specific history and character but also to the uses and to the activities that take place in the park itself. In the maintenance of historical urban green areas in particular, a cautious balancing between the use and preservation of the sites is essential. This research does not pretend to offer a radical solution to this problem but rather aims to present a different point of view to evaluate and explore urban parks. The research was developed in conjunction with the EU Greenspace Project.

2 Personal Safety and Aesthetic

2.1 The Safety Demand

The theme of personal safety related to crime, in European cities, is central in recent research fields and projects, due to an increasing demand from citizens for more liveability of open spaces. In the case of urban green spaces such as gardens or public parks, the diffused concept of crime is related mainly to the "predatorial microcriminality". This expression denotes all the crimes happening in public spaces, reaching the citizen as a pedestrian (ACIERNO 2003). The actual interest to the crime prevention is often called "the second generation of designing out crime" (SOOMEREN 2000). Nowadays, cities after some decennials of crises are growing and attracting more inhabitants, with the aim of being agreeable for citizens and visitors. Directly linked to the question of livablleness, an increasing demand of safety by citizens is increasing. For example, in the Carta Urbana Europea of the Council of Europe presented in Strasbourg in 1992, the theme of safety was
the first point among twenty that was discussed. This theme becomes crucial also because the traditional city had assigned fear specific spaces only to marginal or poor areas but in contemporary cities, the spaces of fear have expanded. The sense of insecurity in fact, is spreading also to the more reached spaces, gaining field in the dense and central areas (ACIERNO 2003).

The current safety demand from the citizens is polyvalent, as the concept of urban safety depends either from the social and objective sphere or from the psychological and subjective sphere. According to psycho-sociology, fear is a fundamental sentiment of the adaptation of humans to the environment, a mechanism deriving from the survival instinct. This research is established on the theory that explains human adaptation in relation to the environmental condition, with reference to the classic authors from DARWIN (1859/1989) and LORENZ (1989), to the studies of KAPLAN (1987) and to the "Prospect and refuge theory" of APPLETION (1996). The work presented here, follows the stream of the psychophysical perception research (WHERRETT 2000; STAMPS 2000), through the application of landscape preference models for simulated urban parks. In particular, people's perception and appraisal of the form of the space is investigated. The analysis is focused on the observation of the characteristics of personal safety and aesthetics. The material of analysis is the urban green, in the form of historical parks and gardens. This type of green, which is full of significance and culture, is often centrally and strategically located but is in some cases underused because of the sense of fear and problems linked to the perception of personal safety.

2.2 The Aesthetics of Urban Green

The composite scenario of the urban green structures, is the result of different sensibilities and subjectivities, expressed by the multiplicity of social experiences and cultural requirements characterizing the urban society. Thus, the investigation to identify the aesthetic significance, the value of the "icons" of the urban parks can be ambiguous. Most of the parks situated in densely populated cities are historical heritages derived from a multiplicity of cultural and perceptive experiences. This research proposes to approach different disciplines, with the aim of creating an interdisciplinary analysis useful for the themes dealing with urban greens and landscapes. The landscape is considered from two different ways: on the one side, the landscape is considered as the environment, the result of physical, ecological and cultural aspects, on the other side, according to a more conservationist tradition, the landscape is evaluated with a specific interest for the visual, physico-morphological and aesthetic aspects.

Urban green is commonly associated to the image of gardens and parks that the urban transformations, ancient and recent, provide in a variety of figurative expressions of typologies and structures. With the recent evolution in the actual form of the urban park, the traditional distinction between garden and park becomes less obvious. However, the new questions on use and methodologies to represent and to design the urban green cannot ignore the principles and the values that generated the actual form of the urban park. Parks and gardens represent two figurative archetypes, based on two distinct aesthetic ideals. The first being the garden derived from the Medieval Latin word giardinum, which stands for a closed and fenced in space. The other is an open spaced garden, bounded and organized with an artificial mark, organized with regular and geometrical schemes. The garden, an allegorical place under the human control, realized with aesthetic ambitions, is often the
surrounding of an architectonic component. The term park derives from the pre-Latin forms of *parra* or *barra* that mean enclosure or border. Indeed the original function of the park was to bind something mobile, such as flocks of animals; this refers back to stock farming or to hunting reserves that are usually located *extra moenia*. The archetype of the modern urban green is the urban park or public park. The function of the urban park, is influenced by the English landscape garden, was to mitigate the effects of the, sometimes, dramatic growth of the industrialized city. In fact, urban parks in European cities engage not only aesthetic, cultural and didactic aims, but also social and hygienic purposes. With the evolution of the concept of urban green in a more functionalistic approach, the traditional typological model of green space was distanced from the aesthetic vision of the nature. The functions of the green space became more important than the coherence to the traditional spatial models. The theme of the urban park was converted more in a social direction and the interest focused on the utilitarian aspect rather that on the aesthetics of the scenic representation of the nature (Migliorini 1992). Thus the theme of the urban green, the conflict between form and use, the question between heritage conservation or new functions, is a very real issue, that can be treated with a new analytical and experimental approach, starting with the understanding of the perceptions and the needs of the potential park users.

### 3 Methodology

The perception of personal safety is strongly related to the presence of visual enclosure (Stamps 2005) and to the conditions of "visual impermeability" (Jorgensen 2002). It is well documented that the presence of dense vegetation in urban parks may induce a sense of fear. In particular, the presence of dense vegetation can contribute to the fear of entrapment, with the presence of barriers of escape, and to the fear of concealment, with the presence of blocked prospects (Nasar & Jones 1997). The research measures and evaluates observers’ response to hypothetical design interventions, such as the reduction of the shrub and bush density, which obstruct the observers’ visibility. The visual impermeability is obtained with the mutual changes of foreground and background vegetation barriers. (Fig. 1).
The interventions are proposed to increase activity in the parks and therefore to improve the sense of personal safety of park visitors. It is also estimated that open design profiles do simplify the orientation in the park and above all reduce potential “hotspots of crime and fear” (Nasar et al. 1993) present in the sites. The aim of the research is to analyze preferences for different scenarios of enclosure in Platzspitz and Zürichhorn, two historical parks situated in the centre of Zürich.

3.1 Visualization and survey design

Using 3D modelling techniques, 128 still images based on quantitative information stored within Geographical Information Systems (IMAGIS ©Cirad) and qualitative data of vegetation types (AMAP ©Bionatics) were generated. The controlled simulated scenarios represent changes or dynamics that might be happening over time in the parks. The design parameters of the visual alternatives for the park were defined by disaggregating the park into visible and influential attributes. The hypothetical scenarios were developed using three main attributes: seasons, points of view, and spatial arrangement of vegetation. The parks, depicted with a high level of detail and realism, are represented over the course of a year (seasonal changes) by a sequence of static images rendered from several points of view, positioned along an imaginative walk in the park. The different enclosure effects are realized with the variation in the amount of foreground and background shrubby vegetation. For each attribute of interest, four attribute levels were determined. From the combination of the three attributes and their four levels of variation, a full factorial study design was created. The full factorial design involves $4^3$ different profiles, which produces 64 context-setting scenarios for each park. All the 64 profiles were visualized with digital images (Fig. 2). The 64 images/profiles visualized were used in four types of evaluation sets. This paper presents the results from the assessment of the 64 images/profiles, independently from the type of evaluation set. In the survey experiment each image/profile has been depicted and assessed 16 times. For each park, a paper survey with a sample of 128 respondents was conducted. The respondents’ sample is composed of four selected groups of 32 interviewees:

- citizen in Zürich
- landscape experts
- interviewee near the park
- interviewee in the park.

The respondents were not informed about the identity of the parks, in order to avoid any possible induction that might influence the evaluation behaviour. Respondents were asked to imagine that they were visiting the depicted park for the first time and were then asked to assess the park, by evaluating the images/profiles using a rating scale, which goes from 1 to 7. The expression image/profile is used in order to clarify the occasional misunderstandings in the visual stimuli evaluation exercises that might occur between "picture or place" (Scott & Canter 1997). In this survey, the interviewee evaluated a park, using some images depicting different controlled visual profiles of the existent situation and possible changes or dynamics.
3.2 Results

From the data collected, it is possible to elaborate on the first considerations about the parks presented. The evaluations are based on the mean values, obtained from 1024 observation for each virtual park. In both the virtual parks, the overall patterns of the responses expressed for the personal safety and the aesthetic show a significant variation between the two characteristics, as illustrated in the histogram of Platzspitz park, which represents the ratings means of all the 64 images/profiles (Fig. 5). The ratings variance confirms the existence of conflicts between personal safety and aesthetic in urban parks. This conflict is also proven in considering the images/profiles that obtained the highest and the lowest mean values for personal safety and aesthetic, as in the case of the Platzspitz park, where the opposition reversing the profiles selected is manifested (Fig. 2). In the next step, the role of the visible and influential attributes is investigated. Hence, the 1024 observations were evaluated in relation to the vegetation spatial arrangement (vegetation) and the seasonal changes (seasons) see Fig. 3 and Fig. 4. As supposed, for the characteristic of personal safety in both the parks, the profiles with the full enclosure (yes yes), are considered as less safe, while the profiles without enclosure (no no) obtained the highest mean values for safety. In both the parks, the safest season is winter, while the less safe is summer. These results confirm that not only the vegetation spatial arrangement but also the density of the vegetation barriers might play a role in the perception of personal safety. From the observations of the aesthetic evaluations, it seems that variability of the vegetation is preferred over uniformity of totally open or fully enclosed spaces. In particular, for the Zürichhorn park, the highest aesthetic means were the ones depicting only one vegetation barrier, placed in the foreground or in the background (yes no / no yes). In both the parks, the less aesthetic season evaluated is winter, while the highest evaluated are spring and autumn. The respondents’ ratings of the 64 images/profiles in both the study cases showed significant responses to the visual attributes adopted and confirmed the hypothesis that the “visual impermeability” influences the assessment behaviour of potential parks users. In the present research, controlled design visualization experiments for the context of the urban park were developed and some reactions of the respondents were described. The future aim of this research is to learn from the respondents’ reactions in order to explicate the assessment behaviours presented in this paper.
Fig. 2: Images/profiles of Platzspitz park. Seasonal changes and different conditions of vegetation spatial arrangements

4 Conclusion

This work is based on the assumption that urban parks, and in particular historical green spaces are figurative archetypes that have to be evaluated in an active way, responding to the exigencies of the citizens, with respect for the cultural and historical references (LANGE ET AL. 2004). The actual issue of the urban green space is the collision between the permanence and the integrity of its forms and materials and on the other side the heterogeneity and the instability of the contemporary cities. The livableness of urban open spaces is measurable, with the possibility to discipline their exercises of liberty and autonomy of uses. Nowadays urban parks have become new spaces of incertitude, as demonstrated by the use of preventive measures, such as the fencing of spaces, or the charging of entrance fees or the presence of guards or police officers. This work investigates the perception of safety in urban parks, with the aim of giving an orientation for the composition of the open spaces, respecting the balance between the form and the use. The ambition is to identify and to quantify possible physical characters in urban parks that might generate spontaneous defensive closing behaviour, in the belief that mental barriers limit the uses of the open spaces, contributing to the generation of decadence and the impoverishment of the quality of the spaces. This study is based on the belief that by observing and analyzing the reactions to different landscape visualizations, it is possible to better comprehend people's preferences and also to better preserve, manage and improve the resources of specific sites, in this case, of urban parks.
Fig. 3: Platzspitz park: means for influential attributes of vegetation and seasons
Fig. 4: Zürichhorn park: means for influential attributes of vegetation and seasons

Fig. 5: Platzspitz park: histogram of means for personal safety (red; in original) and aesthetic (yellow; in original)
5 References

Scenic Quality Modelling in Real and Virtual Environments

Michael ROTH and Dietwald GRUEHN

Abstract

To generate an area-wide map of scenic quality within the regional landscape programme of the German federal state of Saxony, a visual quality model was developed, by order of the Saxon State Agency for Environment and Geology at the Berlin University of Technology, incorporating both real and virtual environments. A broadly based photographic documentation (over 2000 photographs) was created as basis for over 8000 photograph assessments carried out by more than 1000 participants. By the use of a 3D-GIS system and a large dataset of area-wide accessible spatial data, the sites/views of the photographs (located by GPS) were simulated in a virtual environment. Taking both the participants “real” landscape assessments and the landscape components within the GIS/dataset, statistic models for visual quality and its components beauty, variety and peculiarity (according to the German Federal Nature Conservation Act) were developed using SPSS. After this, these models were transferred back into 2D to map scenic quality within the GIS.

The variance of the participants’ ratings can be explained to a degree of 65 % (variety), 48 % (peculiarity), 41 % (beauty) and 69 % (overall scenic quality) by the ordinal regression analysis models developed. It seems possible to improve the models described, if better digital data becomes available (e.g. more precise digital elevation models, more accurate land use classification).

Temporal changes (the 4th dimension of scenic quality) in the landscape as well as in the people’s perception of visual quality can be incorporated in the model presented. It is a dynamic model, which can be used to evaluate different scenarios of future landscape development and to monitor variations in scenic quality as perceived by the public. Thus the model developed is an example of integrating public participation in the research and planning process.

1 Introduction

The Saxon State Agency for Environment and Geology (Sächsisches Landesamt für Umwelt und Geologie – LfUG) as environmental planning authority on the federal state level, is responsible for providing the landscape programme, a plan setting out the “supra-local requirements and measures of nature conservation and landscape management” (Federal Nature Conservation Act § 15). Part of this programme is an area wide evaluation of scenic quality. In 2001, the department of landscape planning, landscape management and nature conservation at the Berlin University of Technology was commissioned to develop a scenic quality evaluation method and to perform the scenic quality assessment
This paper presents some of the results of the research done between November 2001 and May 2003 (GRUEHN et al., 2003, unpublished). Different requirements had to be fulfilled when developing the new scenic quality evaluation method:

- The method had to be developed on an empirical basis, making public participation an integral part of both the research progress and the actual evaluation results.
- Scientific quality criteria had to be taken into account. The reliability and validity of the method and its results had to be investigated.
- The scenic quality components of variety, peculiarity and beauty used in the Federal Nature Conservation Act had to be assessed as well as overall scenic quality.
- The whole method had to be compatible with GIS (in this case ESRI’s ArcView 3.3 used at the LfUG). Statewide accessible spatial data had to be used for the assessment and there was no possibility of mapping new data due to financial and time constraints.

Regarding the definition of landscape and scenic quality, the psychological-phenomenological approach of NOHL (2001, p. 43) was followed, which distinguishes between landscape and scenic quality as figure 1 shows.

![Interdependence of landscape, viewer and scenic quality](image)

**Fig. 1:** Interdependence of landscape, viewer and scenic quality (NOHL, 2001, p. 44, modified).

## 2 Method

The basic structure of the research project is shown in figure 2. Following the psychological-phenomenological approach described above, it was assumed that landscape

(real or photographic representation) evokes scenic quality “in the eye of the beholder”. This reaction can be estimated by means of surveys, using 25 criteria taken from different scenic quality evaluation methods (e.g. abwechslungsreich/diversified, schön/beautiful, typisch/typical), not only for individuals, but also for a population. The image evoking landscape components are represented in the digital landscape data set and can be measured objectively within a GIS. If statistic analysis reveals a significant and validated interrelationship between GIS-based landscape components and the participants’ scenic quality ratings, this result can then be used for the area-wide modelling of visual quality within the GIS.

After finishing the theoretical preparatory work, a photographic documentation of Saxon landscapes was built up. 2148 photographs were taken at 311 sites, distributed over the 32 natural regions (classified by Bernhard et al., 1986). Up to 47 pictures were taken at each site, covering both different view directions and different seasons (up to 3 site visits). To exactly locate the viewpoints, GPS was used. Additionally, the view directions and the site descriptions were recorded in a database and in a topographical map.

To collect people’s subjective impressions of scenic qualities, different questionnaires were developed, containing demographic data, ratings of scenic qualities and estimations of landscape components. Including several pretests, 7 different questionnaires were used. Table 1 shows the content of the questionnaires and the sizes of the samples.
Tab. 1: Overview of questionnaire contents and sample sizes

<table>
<thead>
<tr>
<th>Questionnaire/Sample</th>
<th>Content</th>
<th>Sample Size</th>
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<tbody>
<tr>
<td>pretest landscape ratings vs. photograph ratings</td>
<td>demographic data, scenic quality ratings (25 criteria)</td>
<td>17 sites/photographs 30 participants each ≈ 510</td>
</tr>
<tr>
<td>pretest saxon people vs. people in/around Berlin</td>
<td>demographic data, scenic quality ratings (25 criteria)</td>
<td>55 photographs 50 participants each ≈ 2750</td>
</tr>
<tr>
<td>pretest landscape assessment experts vs. laymen</td>
<td>demographic data, scenic quality ratings (25 criteria)</td>
<td>10 photographs 60 participants each ≈ 600</td>
</tr>
<tr>
<td>pretest farmers vs. non-farmers</td>
<td>demographic data, scenic quality ratings (25 criteria)</td>
<td>10 photographs 107 participants each ≈ 1070</td>
</tr>
<tr>
<td>pretest different seasons, foliated vs. non-foliated vegetation</td>
<td>demographic data, scenic quality ratings (10 criteria), landscape components (15 criteria)</td>
<td>34 photographs 38 participants each ≈ 1300</td>
</tr>
<tr>
<td>pretest reliability of landscape ratings</td>
<td>demographic data, scenic quality ratings (25 criteria), landscape components (31 criteria)</td>
<td>20 photographs 2 participants each ≈ 40</td>
</tr>
<tr>
<td>landscape components survey</td>
<td>demographic data, scenic quality ratings (25 criteria), landscape components (31 criteria), qualitative data (10 open questions)</td>
<td>130 photographs 34 photographs 38 participants each ≈ 650</td>
</tr>
<tr>
<td>main survey</td>
<td>demographic data, scenic quality ratings (10 criteria)</td>
<td>200 photographs 30 participants each ≈ 6000</td>
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To bring the participants photograph-based ratings (perspective view of three dimensional landscape) and the 2D and 3D digital data (for the content of the dataset used, see table 2) together to produce a two dimensional map of scenic qualities, a GIS-based, three dimensional viewshed analysis was used, putting a virtual viewer at exactly the same position where the rated landscape photographs were taken. Figure 3 shows an example of this analysis. The very basic 3D-visualization in figure 3 is used to illustrate the virtual viewers sight of the digital dataset and to check the viewshed analysis for plausibility. It was not presented to the survey’s participants.

Tab. 2: The dataset used for viewshed analysis/visual quality modelling

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Content</th>
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<tbody>
<tr>
<td>ATKIS DLM 25/1</td>
<td>digital, vector based topographic data, original scale 1:25000</td>
</tr>
<tr>
<td>ATKIS DGM 25</td>
<td>digital elevation model, grid, horizontal resolution 20 m, vertical resolution 0.1 m</td>
</tr>
<tr>
<td>CIR-based habitat mapping</td>
<td>digital, vector based habitat data, point, line and polygon layer, recording scale 1:10000</td>
</tr>
<tr>
<td>thematic data layers</td>
<td>wind turbines, power plants, open cast mining sites, overhead lines, dumpsites,...</td>
</tr>
<tr>
<td>nature protection areas</td>
<td>different types of nature reserves</td>
</tr>
</tbody>
</table>
Based on the results of the landscape components survey, the correlation of the photograph’s content (as representation of the real landscape) and the landscape components in the digital dataset (as seen by the virtual viewer) was computed using SPSS. So it was possible to develop a statistical model for different scenic qualities (variety, peculiarity and beauty as well as overall scenic quality) based on the participants ratings in the main survey (over 6000 photograph ratings for 200 different views) and the landscape components in the digital dataset. This model then was applied to the whole area of the federal state of Saxony, using a grid of 2500 m resolution as spatial basis.
3 Results

All the pretests performed were successful, and allowed to use the workflow described above to generate scenic quality maps. Due to the limited space, only the most important results of these pretests are described in the following paragraphs:

- There was a strongly significant correlation between people’s rating of real landscapes and their photograph based ratings of the same views for all 25 criteria in this investigation ($p < 0.001$; Spearman’s $r > 0.7$ except for one criterion where Spearman’s $r = 0.687$). This corresponds with the results of previous research (e.g., Hershberger & Cass, 1973; Nohl, 1974; Daniel & Boster, 1976; Hull & Stewart, 1992; Scott & Canter, 1997) and allows to take colour photographs as surrogates for the real landscape experience in this and similar studies.

- The differences between Saxon people’s ratings and the ones of people living in or around Berlin are either not significant (2 of the 25 criteria) or the influence of people’s origin on their scenic quality rating is less than 5% ($\eta^2 < 0.05$ for 22 of the 25 criteria) and can therefore be neglected according to the thresholds given by Bortz (1999, p. 137). For the criterion “typisch” (typical) an influence of people’s origin above this threshold (but only marginally higher: 5.4%) could be observed.

- Expert’s and lay people’s scenic quality ratings don’t differ very much: For 15 out of the 25 criteria rated, no significant differences could be observed. For further 9, the influence of the expert status on the scenic quality rating is smaller than 5%. Again, only when rating the typicality of a landscape, experts and lay people differ, but the influence can nevertheless be classified as very small ($\eta^2 = 0.064$).

- Some authors, for example Winkelbrandt & Peper (1989) developed scenic quality models which require landscape analysis through the entire course of one year. As this means a huge burden for any researcher or practitioner, it was tested whether there are significant and relevant differences between scenic quality (as perceived by people) in different seasons respectively different vegetation foliage states. The mean differences for all scenic quality criteria and landscape components estimations were smaller than $\pm 0.65$ (on an 11-step scale). Only 4 of these mean differences were actually significant (total aesthetic value, vegetation density, portion of forest area and visible hedge length). With a maximum influence of 1.1% (hedges), different seasonal aspects were not considered relevant for the further project.

- All the demographic factors (sex, age, school and professional qualification, importance of nature and environment, frequency of outdoor trips) determined the scenic quality ratings to a degree of less than 1% ($\eta^2 < 0.01$) if they were significant at all. Therefore, there was no necessity to draw stratified random sub-samples as long as there were no biased samples.

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¹ The more elements a sample gets, the higher is the chance that even a small effect becomes statistically significant. Therefore to estimate the influence of the factors investigated on scenic quality ratings, the effect size $\eta$ and the portion of explained variance $\eta^2$ are used.
A statistically very significant \( p < 0.01 \) and quite strong \( 0.5 \leq r \leq 0.8 \) correlation could be observed between the landscape photographs’ content as perceived by the participants and the landscape components as “seen” by the virtual viewer in the digital data set (e.g. 0.51 for land use diversity represented by the number of different types of land use, 0.63 for relief energy, 0.55 to 0.76 for the portions of the main land use types, 0.8 for the range of vision). Whereas the photographs presented to the participants represented the three dimensional view of the landscape for the virtual viewer, the amount of landscape components in the two dimensional projection of the field of vision and not the three dimensional virtual image was analysed. This was necessary for different reasons:

1. When the statistical model for visual quality mapping was developed, it was essential to assess the scenic quality of a certain surface area according to its impact on a potential viewer, which might not be identical with the scenic quality the viewer perceives when standing on this area. Therefore, the content of the viewshed area and not the content of the view were considered as relevant parameters for the scenic quality models. Figure 4 shows the difference between these two possibilities of viewing direction.

2. From a technical point of view, it was quite a huge effort to calculate the statistical model for scenic quality based on a grid with more than 3000 cells (with a size of 2500 m x 2500 m). It would have been nearly impractical to do viewshed analysis for thousands of viewpoints.

3. It was one goal of the project described to deduce planning objectives and measures. As the scenic quality of a particular area (represented by a grid cell) was assessed according to the method described on the right side in figure 4, it was easy to identify whether a certain region should be conserved, managed, developed or restored.

Finally, visual quality models were developed for variety, peculiarity, beauty and an overall scenic value. Figure 5 shows the map of visual variety as one example of these models. This model incorporates land use variety, relief, the area of water bodies, the area of agricultural fields, the forested area and hedge length. The statistical quality of this model is measured using Nagelkerke’s pseudo R-square which corresponds to the R-square in...
linear regression analysis. For variety a pseudo R-square of 0.65 was achieved which means that 65% of the variance of visual variety can be explained by the factors mentioned. For peculiarity pseudo R-square reached 0.48 and 0.41 for beauty.

Fig. 5: Area-wide map of visual variety as an example of the ordinal regression analysis models developed. Darker grid cells represent higher visual variety.

4 Discussion

The central point in visual quality modelling - as with all other models - is validity. Our scenic quality models can be judged concerning their validity by using the measure described above (Nagelkerke’s pseudo R-square). The models explain between 41% and 65% of the scenic quality components that were acquired in the broadly empirically based survey. Looking at the explained variance of other scenic quality models found in literature (36% with HUNZIKER & KIENAST (1999) based on image diversity/contrast; 54% with PALMER & LANKHORST (1998) calculating spaciousness based on landscape objects; 57% with BISHOP et al. (2000) based on land-cover; 80% with BISHOP & HULSE (1994) based on land-use and relief/slope), the results of the study presented confirm the amount of explainable variance by using models based on area-wide accessible digital data. One aspect that distinguishes the study described in this paper from nearly all other models listed above is the size of the study area. The federal state of Saxony has an area of more than 18000 km² whereas BISHOP & HULSE (1994) mapped scenic beauty within an area of about 10 km². Considering this huge scale difference, the large dataset and the fact that all calculations could be performed on a standard PC, the explained variance of the model developed seems quite satisfying.
To set up the statistical visual quality model, different types of regression analyses were computed. First, multiple linear regression analysis was used to develop models for the components of visual quality mentioned in the Federal Nature Conservation Act (variety, peculiarity and beauty) and to isolate the survey’s scenic quality criteria most suitable to represent those components. There were different problems with the linear regression analysis, so that in the end, a model based on ordinal regression analysis was used:

- The ordinal regression analysis, which does not rely on the interval scale or normal distribution requirement, is a more appropriate and efficient tool from a mathematical point of view.
- Linear regression analysis implies that there is a linear relationship between - in our case - landscape components and visual quality. This is obviously doubtful, as Bishop (1996) describes. Ordinal regression analysis also allows to include non-linear relationships in the model. One example of such non-linear relationship is the influence of the percentage of forested area on scenic variety. Variety rises with an increasing portion of forests, but at a certain stage, a further increment of forested area leads to decreasing visual variety. Due to the better representation of these interrelationships, ordinal regression analysis delivered statistically more valid models than linear regression analysis.

As no polygon boundaries suitable for visual quality modelling were available, the scenic quality map(s) had to use a grid as spatial basis. Regarding the grid cell size, there are two opposing demands: To derive specific planning measures, a small cell size seems desirable whereas a larger cell size seems to better represent the average viewshed area in Saxony. Different authors recommend to limit the “middleground” (where landscape components still can be clearly distinguished) at up to 5 km distance from the viewer (Nohl, 2001, p. 81). To balance those two requirements, a correlation analysis between different cell sizes’ (5000 m, 2500 m, 1250 m) amounts of landscape components was carried out. An average correlation of about 0.75 could be observed between the 5 km grid and the 2.5 km grid, whereas the correlation between the 5 km grid and the 1.25 km grid were considerably lower. For these reasons, the 2500 m grid was used for all the analyses described.

As different scenic quality estimation methods used in German planning practice sum up different components of visual quality in an overall aesthetic value (e.g. Adam et al., 1986; Wöß, 2002; Hoisl et al., 1989), two different ways of generating such values were investigated: First, an ordinal regression analysis based on the scenic quality components variety, peculiarity and beauty was computed. The best model explained about 69% of the criterion overall scenic preference within the survey, but consists only of the two components variety and beauty with a dominant influence of beauty. This indicates that overall scenic quality is nearly congruent with beauty (a correlation of about 0.9 with a statistical significance of p < 0.001 could be observed in the main survey). Second, a simple allocation of the maximum value of variety, peculiarity and beauty into the overall aesthetic value was performed. This fulfilled the requirements of the Federal Nature Conservation Act to conserve the diversity, characteristic features and beauty of nature and landscapes, as a high value for one component can’t be averaged to a lower overall value by the other components.
5 Conclusion and Outlook

Even though the results of the study presented are quite satisfying, a fraction between 35% and 59% of unexplained variance for the different scenic quality components remains. It is not realistic to explain 100% of scenic beauty as perceived by human beings, as there are several subjective preconditions determining scenic quality, but several ways of improving such models seem to exist. With a better data quality (higher accuracy in respect of content and spatial resolution) and better computer performance, more complex models can be calculated. To distinguish the fore-, middle- and background in viewshed analysis and to incorporate neighbourhood relationships in the model could be one improvement. BISHOP (1996) demonstrated the predictive capability of neural net based approaches in scenic beauty evaluation, which might be a second possible way of incorporating non-linear relationships into visual quality models.

Another approach of visual quality modelling in virtual environments could be the reversion of the line of sight as described in figure 4 (left side of figure). As described above, this approach delivers different results than the one presented in this paper but might be of value for solving different problems.

Temporal changes (the 4th dimension of scenic quality) in the landscape as well as in the people’s perception of visual quality can be incorporated in the model presented. Different future scenarios of land use and landscape development can be evaluated by taking the different land use datasets as basis for visual quality modelling. Another way of including time into the model is to repeat the surveys within a 10 or 15 year period to monitor potential changes in scenic quality perception and to fit the model according to these changes. Anyway, empirical scenic quality models are an example of public participation in landscape research and landscape planning and might help to increase the importance of scenic aspects in environmental planning.

6 Acknowledgments

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7 References


1 Introduction

Haydelberga is an interdisciplinary project developed from a co-operation of architects, historians and software-developers with the target to advance existing results in the field of virtual reality (VR) and to allow the new generated products to be applicable in different fields of investigation and economy.

The historic simulation of the whole ancient city of Heidelberg of the year 1620 is a pilot project- built exemplarily in interactive real time and in 3D-stereo.
2 Project Description

At first model structures were developed for the product (for data and enquiry to the generation of mass models and block models and their further modelling up to the transfer and processing in the VR-system).

For modifying the standard softwares several software modules were developed, which guarantee an optimized connection for the continuousness from the enquired and processed data of the different data compounds across the modelling of the data up to the 3D-visualisation. The giant data amounts necessary for the extensive 3D-modelling and the interactive possibilities of presentation (eg. animated simulations) are excellently transposed by specific adaptations and structures.

The historic data for the project Haydelberga were researched by cultural scientists and historians and converted into virtual reality in co-operation with and by architects and software specialists.

For the converting of the researched data and the developed data structure into the entire model the @Last Software and the awaron ag could be gained as co-operation partners in the domain of software.

@Last Software is the manufacturer of Sketch Up, a small and powerful 3D real-time modelling software with excellent integration. Sketch up guarantees fast and effective use by its intuitive usability and powerful tools.
The VR software *tucan* by *awaron ag* was elected as visualisation software. One excellent feature is its flexibility and the integration of nearly any external media and data such as videos, HTML-pages, graphic material, external software etc.. The render-engine provides high frame rates even with largest data amounts.
3 Possible Applications

The developed technique – applied to the illustration of the entire city structure of the destroyed historical Heidelberg – turns the project Haydelberga into a pilot project for manifold applications and further developments, e.g.:

- (Historical) Urbanistic visualisation
- Interactive visualisation of cities in present time
- Integration into graphic information systems (GIS) and spatial classification systems
- Product presentations in various fields
- Virtual instruction manuals
Real-Time Rendering of Landscapes Using VRML with Graphic User Interface

Tsuyoshi HONJO, En-Mi LIM and Kiyoshi UMEKI

1 Introduction

In landscape planning, the feedback process from user to planner as shown in Fig. 1 is important. The application of virtual reality to landscape or real-time rendering of the landscape is a powerful tool for the feedback process and for precise recognition of the plan. There have been many studies on visualization of terrain by virtual reality and Virtual Reality Modeling Language (VRML) (DOYLE ET AL., 1998; MOORE ET AL., 1999; HUANG & LIN, 1999; LIN & WANG, 1999; HUANG & LIN, 2002; MORRISON & PURVES, 2002). But in these studies, practical design of landscaping including plants were not shown. HONJO & LIM (2001) developed a system for real-time rendering of landscapes using VRML and models of plants were included in the system. With the system called ‘VR-Terrain’, landscapes of parks and gardens with thousands of plants can be visualized in walk-through mode using VRML. LIM & HONJO (2003) also developed an advanced version of VR-Terrain for forest landscape visualization. Landscape models created with the system can be easily transferred through the Internet providing real-time virtual experience of walk-through simulations of planned landscapes to a broader audience.

In this study, we developed a system for real-time rendering of landscapes using VRML with graphic user interface (GUI). With the system, which we named GUI version of VR-Terrain (VRT-GUI), VRML models of landscapes can be generated very effectively. The system has powerful sub-systems which model terrain, buildings and plants. The system can model landscapes of residential areas, urban and suburban areas and natural forest.

Fig. 1 Process of landscape planning using visualization by VRML.
2 Methods

2.1 About VR-Terrain

VR-Terrain is a system that was optimized for landscape visualization and it automatically generates the VRML model from landscape data. Basic elements of landscape are plants, terrain and architecture as shown in Fig. 2. The visualization procedure consists of collection of the 3D data and conversion of the data to VRML format by using VR-Terrain. To use the VRML, a browser that supports VRML is necessary. In this study, the free Cortona VRML Client (Parallelgraphics, http://www.parallelgraphics.com/) was used with Internet Explorer (Microsoft).

2.2 Modeling of Terrain

In VRML, when there are digital elevation modeling data (DEM) on a grid, terrain is easily visualized by using a node (command used in VRML) called ElevationGrid. When the elevation data of ground control point (GCP) are not on a grid, grid data for elevation, \( h \) is calculated by interpolating the original existing elevation data. Interpolation is done by following equation:

\[
\hat{h} = \frac{\sum h_i \cdot d_i^{-1}}{\sum d_i^{-1}},
\]

where \( h \) is elevation of the calculated grid, \( h_i \) is a elevation of GCP and \( d_i \) is a distance from point of \( h \) to point of \( h_i \). Used control points are located in 2 x m square grid.

![Fig. 2 Visualization procedure of landscape using VRML](image-url)
By mapping a photorealistic texture on the terrain, the graphic realism of the representation is improved. Texture mapping is also used with the ElevationGrid node.

2.3 Modeling of Plants and Plant Database

In VR-Terrain, we used the plant models from AMAP, which is a modeling system of plants developed by CIRAD. AMAP is one of the outputs of the plant research of DE REFFYE ET AL. (1988) and was applied in many studies (HONJO ET AL., 1992; SAITO ET AL., 1993; PERRIN ET AL., 2001). AMAP can produce 3D models of more than 300 species of plants and also can simulate the plant growth. In AMAP, effects of season and pruning can be visualized (Fig. 3).

The number of the polygons of 3D model varies between thousands to millions. These polygon models need long rendering times. A billboard approach is very effective for faster plant rendering; The 2D texture of plants which are in a transparent GIF format are mapped on a plane and two planes are crossed to each other.

We made a database with more than a thousand 2D images of AMAP plants and changed the resolution of 2D plant images according to objectives and scales of planning.

Fig. 3   Effects of AMAP in the image database
2.3 Modeling of Architecture

Some CAD systems have export functions to generate VRML models, but it is time-consuming to design architecture with CAD and generated VRML models. We developed a more efficient approach, a sub-system for designing architecture in VRML. The system is very powerful and flexible and can make any kind of architecture, from small houses to skyscrapers, by changing parameters (Honjo & Lim, 2003). The design interfaces of the system are shown in Fig. 4. By the GUI, placement of objects can be done in each menu (wall and roof, window and door, tree). Architectural models are stored and used in VRT-GUI.

Fig. 4 Design interfaces for making architecture
2.4  GUI Version of VR-Terrain

In Fig. 5, interfaces of VRT-GUI are shown. There are layers for roads, trees (plants), buildings (architecture) and terrain. In the road layer, scales of roads can be changed. In the tree and building layer, objects are effectively placed by using GUI. In the terrain layer, coordinates of GCP points are inserted through GUI.

Fig. 5  Interfaces of the GUI version of VR-Terrain

Fig. 6  Generation of VRML image
After the design of the scene is done, the VRML model is automatically generated; Visualizations in a browser window are shown in Fig. 6.

3 Results and Discussion

3.1 Performance of GUI Version of VR-Terrain

In this study, the landscape of existing an residential area was simulated by VRT-GUI. At first, buildings were designed by using the sub-system. Examples of houses and buildings are shown in Fig. 7. These buildings were placed, and data of plants and terrain was added.

![Fig. 7 Examples of VRML models of buildings](image)

In Fig. 8, the photographs of the residential area and its simulated images made by VRT-GUI are shown. It will also be possible to make simulated images of the planned future. This plan is spatially simulated and detailed discussion is made possible because the VRML models can be accessed in the Internet where users can walk-through the 3D landscape in real-time.
3.2 Education of landscaping by VR-Terrain

With the GUI interface, the efficiency of generating the virtual landscape is remarkably increased. For the new user, it takes less than an hour to learn how to make the planned landscape.

We used VRT-GUI for the education of landscape design. It took less time for the students to become accustomed to the GUI than to the previous interface. The concept of the plan could be intuitively visualized by the system and interactive improvement of the design was possible by changing GCP, vegetation and ground texture.

4 Conclusion

In this paper, we introduced VRT-GUI and an application of the software system in landscape design was shown. Visualization by VRML is an effective way to present the concepts of the proposed plan. VRT-GUI is suitable to generate VRML models of landscapes for an Internet presentation. We expect that the system will have wide practical uses in landscape and urban planning and design.

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6 References


