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The Degree of Realism of GIS-Based Virtual Landscapes: Implications for Spatial Planning

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ABSTRACT

Communicating planning results within expert groups or to local citizens is crucial for the planning process to be efficient. Although 2-dimensional representations are still predominantly used in spatial planning, recently digital 3D-visualizations have become more common. However, the validation of simulations of virtual landscapes regarding their degree of realism has so far been neglected in research.
By modelling a GIS-based virtual landscape encompassing the region of Schwyz and Ingenbohl-Brunnen in Central Switzerland, it is investigated to which degree the real visually perceived landscape can be validly represented by a digital virtual landscape.

1. GIS-BASED 3D-VISUALIZATION

There exist a number of conventional analog as well as digital representation techniques which can be used in spatial planning (see Lange 1999a). The basic elements of the landscape which need to be represented for planning purposes are terrain, built objects and vegetation. Nowadays digital terrain data is widely available at various resolutions. The actual land use information can be represented through imagery acquired through remote sensing. Like terrain data image data is a common data source being used. However, the resolution of satellite imagery is still often fairly low or the recorded color bands are not covering a spectrum as it is perceived by the human eye.
For the digital visual simulation a virtual model of the study area consisting of various elements like e.g. a digital terrain model, digital imagery and various kinds of land use data is assembled. The terrain is visualized through the DHM 25 terrain model of the Federal Office for Topography. It is an elevation model based on a 25 m grid derived from the 1 : 25 000 topographic map.
In order to get a landscape with texture information, digital imagery can be draped over the terrain. The satellite image used is a Landsat TM scene at 25 m resolution, resampled from 30 m. The digital orthophoto (SwissPhoto) has a resolution of 2.5 m. Although imagery is available which has a higher resolution, for reasons of practicality the lower resolution of 2.5 m is used.
Vegetation is represented based on the analysis of the digital topographic map (the so-called 'Pixelmap', scale 1 : 25 000) of the Federal Office for Topography using pattern recognition techniques (Nebiker & Carosio 1995, Stengele 1995). The pattern recognition technique was developed and carried out by the Institute for Geodesy and Photogrammetry at ETHZ. Based on the same principles the Federal Office for Topography is currently producing vector data covering the whole of Switzerland, thereby providing the necessary base data for the general public in the near future.
The resulting 2-D data sets are handled through ARC/INFO. The described vegetation can be transformed into the 3-D environment by setting them on the terrain surface and creating polygonal objects on which the appropriate tree textures can be mapped (Hoinkes & Lange 1995). This procedure is done by using Polytrim software which is developed at the Centre for Landscape Research at the University of Toronto (see Danahy & Hoinkes 1995).
Also, the footprints of the buildings can be exported from the GIS to the visualization system to create building volumes based on predefined attributes (height of the building).
For the detailed representation of built-form texture-mapping is used in the foreground. For this step manual modelling is needed.

2. EXPERIMENT

A simulation, today mostly in digital format, is always more or less an abstraction of the complex reality. Mandelbrot (1983, p. 1) characterizes the fundamental problem of the digital representation of natural phenomena as follows: 'Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line'.
A comprehensive definition of the term ‚realistic' is given by Hall (1990, p. 191): 'creating an experience that is indistinguishable from the real experience; generating the same stimulus as the real environment; generating the same perceptual response as a real scene; creating the impression of a real scene'. Realism is determined by the following key elements (ibid. p. 195): 'the impression of realism does not necessarily require correct imagery in terms of geometric detail as long as the general behavior is reasonable; that high image complexity is primary in creating the perception of realism; that subtle shading and surface detail are key in creating the perception of realism'.
Therefore, it can be argued, that even simulations with a lower degree of realism can still contain the most important information needed for a specific purpose. E.g. representations used in flight simulation have to have an overall realistic impression without having to contain detailed landscape features. Most important for these kinds of applications are factors like functionality and interactivity and having the ability to display e.g. potential obstacles which could be of importance during the landing procedure.
In order to determine the degree of realism an empirical study is conducted. Using scaling techniques test persons are asked to freely order a set of sample images, which are varying in detail, according to the degree of realism on a scale ranging from 1 - 5 (very low - very high).
The combination of the elements used in the simulation, define through their presence or absence the variation in the virtual landscape used as sample images in the test:

Element terrain

- pure terrain
- terrain with LANDSAT TM satellite image
- terrain with LANDSAT TM satellite image and orthophoto

Element buildings

- not present
- buildings as volumes
- buildings as volumes and buildings with texture (only in the foreground-scene)

Element single trees

- not present
- single trees with texture

Element forest

- not present
- forest with texture

The whole test set consists of 90 images depicting the virtual landscape of Brunnen / Schwyz as seen from three different viewpoints. Three images are photographs from the three different viewpoints (a background-scene, a middleground-scene and a foreground-scene). Another 86 images are corresponding computer-generated images with different representation levels. One image is a composite of photo foreground and virtual background.

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The test set is evaluated by 75 test persons, grouped in experts, lay persons, local experts, and local lay persons. Experts are defined as people practicing or being educated in a discipline related to spatial planning, such as architecture, landscape architecture, forestry, geography, etc. Locals are those persons living or working in the towns of Brunnen and Schwyz.

3. RESULTS

The results gained through Analysis of Variance and descriptive statistic techniques clearly show that by far the most important variable positively contributing to the degree of realism is the terrain with the draped high-resolution aerial orthophoto (see tables 1 – 3). Second most important is the variable buildings. The evaluation is significantly influenced in a positive way if texture-mapped built-form is displayed (the detailed results can be found in Lange 1999b).
Overall the background-scene is rated with the highest degree of realism with the real scene getting a value of 4.747 (R'Degree) and the highest rated computer-generated image getting 4.307 (see figures 1 and 2). The highest rating for the middleground-scene is 3.013 (figure 3). The foreground-scene gets a value of 2.587 without texture-mapped buildings and 3.48 with texture-mapped buildings (figures 4 and 5). The background-scene reaches a degree of realism which makes it very hard to identify it as a computer-generated image. The middleground- and the foreground-scene score lower because of their relatively lower level of detail.

	Min.	Max.
Shaded Relief	1.147	1.84
Satellite Image	1.68	2.68
Orthophoto	4.067	4.307

Table 1: Degree of realism: background-scene (average, ratings by all).

	Min.	Max.
Shaded Relief	1.08	1.747
Satellite Image	1.347	2.493
Orthophoto	2.147	3.013

Table 2: Degree of realism: middleground-scene (average, ratings by all).

	Min.	Max.	Max. (Buildings without Textures)
Shaded Relief	1.053	1.973	1.533
Satellite Image	1.693	2.827	2.12
Orthophoto	2.213	3.48	2.587

Table 3: Degree of realism: foreground-scene (average, ratings by all).

Looking at the scores of the four sub-groups it can be said that they mostly show a similar rating pattern (see tables 4 – 8). However, the group consisting of the local experts reacts sensitive to the presence or absence of buildings in the foregound-scene. This is the only group which gives those images a significantly lower rating where buildings are not depicted in the simulation, i.e. recognizing the absence of the buildings which are present in the original photograph.

Figure 1: View from the Großer Mythen (real landscape).

	Ranking	**R´Degree**	St.Dev.	Median	Modus
All	3	4.747	0.634	5	5
Non-local experts	1.5	4.926	0.378	5	5
Non-local lay persons	2	4.857	0.35	5	5
Local experts	3	4.769	0.421	5	5
Local lay persons	3.5	4.429	0.955	5	5

Table 4: Evaluation of the view from the Großer Mythen (real landscape).

Figure 2: View from the Großer Mythen (virtual landscape).

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	Ranking	**R´Degree**	St.Dev.	Median	Modus
All	5	4.307	0.765	4	5
Non-local experts	6	4.259	0.75	4	4
Non-local lay persons	8	4.357	0.61	4	4
Local experts	5.5	4.385	0.625	4	5
Local lay persons	5	4.286	0.933	5	5

Table 5: Evaluation of the view from the Großer Mythen (virtual landscape).

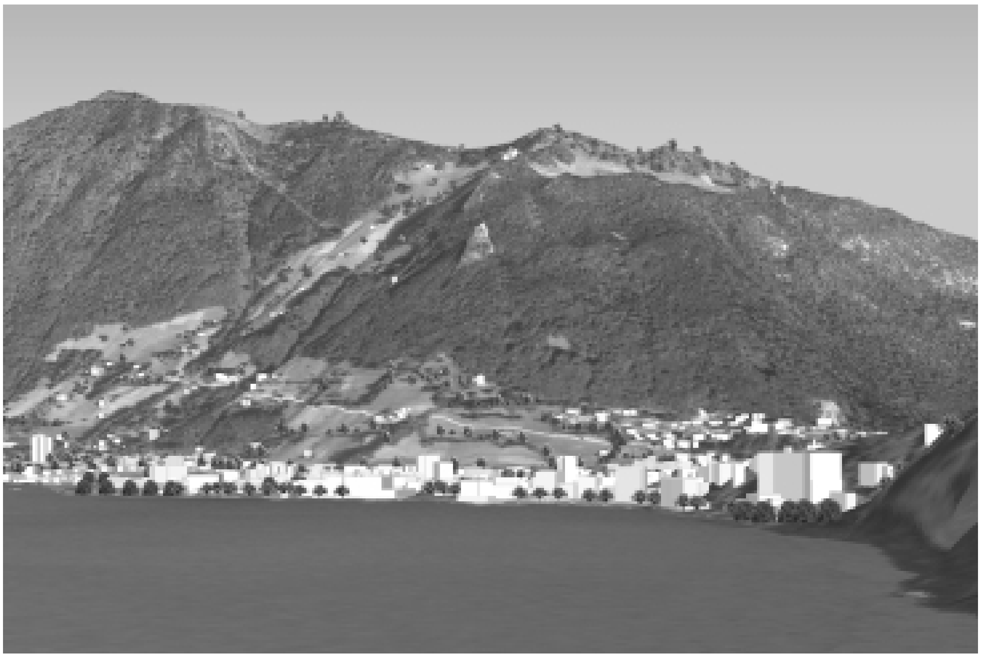

Figure 3: View towards Brunnen (virtual landscape).

	Ranking	**R´Degree**	St.Dev.	Median	Modus
All	20	3.013	0.856	3	3
Non-local experts	21	2.926	0.766	3	3
Non-local lay persons	20.5	3.143	0.833	3	3
Local experts	17	3.154	0.769	3	4
Local lay persons	19	2.952	0.999	3	3

Table 6: Evaluation of the view towards Brunnen (virtual landscape).

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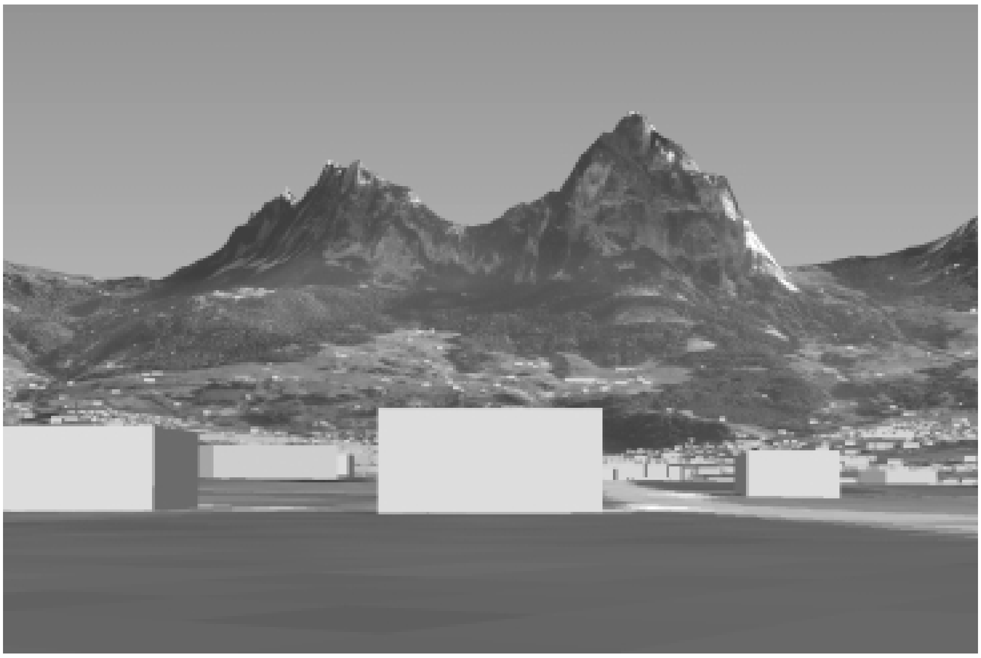

Figure 4: View towards the Mythen (virtual landscape).

	Ranking	**R´Degree**	St.Dev.	Median	Modus
All	31	2.587	0.896	3	2
Non-local experts	24	2.741	0.699	3	3
Non-local lay persons	37.5	2.5	0.982	2	2
Local experts	28	2.615	0.923	2	2
Local lay persons	34.5	2.429	1.003	2	2

Table 7: Evaluation of the view towards the Mythen (virtual landscape).

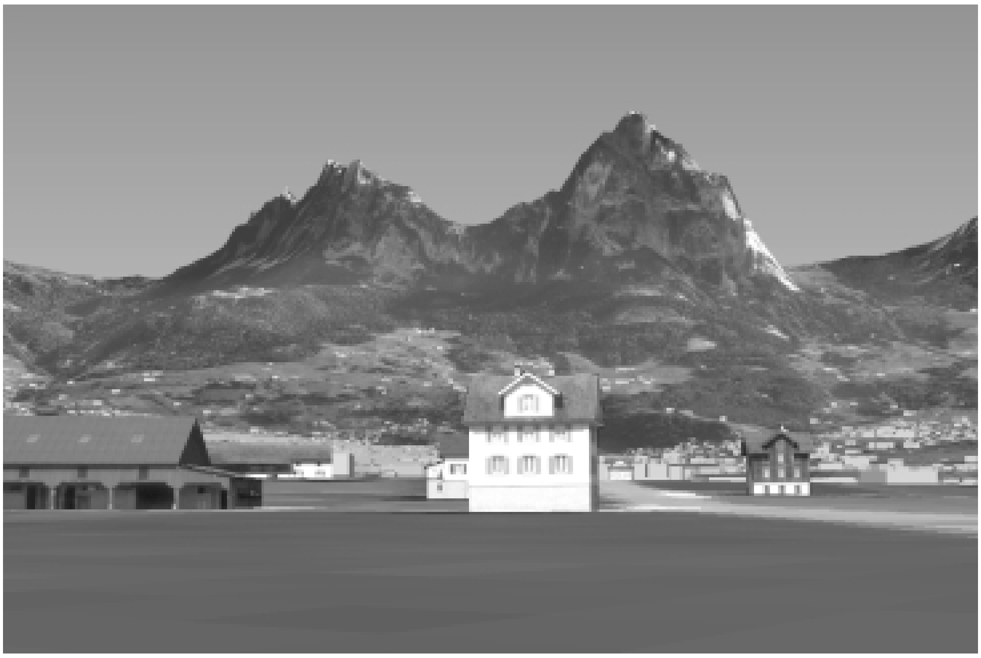

Figure 5: View towards the Mythen, buildings with textures (virtual landscape).

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	Ranking	**R´Degree**	St.Dev.	Median	Modus
All	13	3.48	0.87	4	4
Non-local experts	16	3.296	1.012	3	4
Non-local lay persons	13	3.643	0.479	4	4
Local experts	12	3.692	0.821	4	4
Local lay persons	13	3.476	0.852	3	3

Table 8: Evaluation of the towards the Mythen, buildings with textures (virtual landscape).

4. IMPLICATIONS FOR SPATIAL PLANNING

The planning disciplines have only just to begun to utilize 3D-visualization techniques. The potential use is manifold. Visualizations are typically only very loosely integrated in the planning process, thought of as a sometimes expensive supplement to sell the final planning product, i.e. being the icing on the cake. If one coherent data source could be used during the various steps of the planning process then the factor cost could be dismissed and 3D-visualizations could also be integrated early in an exploratory phase thereby contributing to better and more informed decisions on the environment.

With the exception of digital terrain and remote sensing data, most of the data currently available for 3D-visualization are only covering parts of Switzerland. In the future more 2D-data as well as 3D-data will be readily available. This will be the basis for a shift from the traditional 2D-planning towards 3D-planning which could be offering improved support for better decisions about the spatial organization of the landscape.

The generated simulations as described above can be valid representations of the real landscape. Therefore, based on the computerized visual simulation of the landscape past landscape changes and their related visual quality can be evaluated as well as possible future changes.

5. ACKNOWLEDGEMENTS

Digital orthophoto © Swissphoto Vermessung AG

Digital map data PK25/DHM25 reproduced by permission of Federal Office of Topography, 31.5.1999

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