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Animating Geodata Exemplified by the Dresden „Altai-GIS“

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Keywords: cartography, animation, GIS, Altai, snow dynamics, virtual flight, visual communication

Summary: Compared to static geodata presentations, animations obviously perform superior in displaying temporal dynamics. Dynamic sequences also help in adjusting the information flow to the user's capabilities.

From the Dresden „Altai-GIS“ animated sequences have been produced. Several transformations of GIS data must precede the generation of the animation: Properties of the final display media, the complexity of the geometry model, the field of view of the virtual camera, the integration of secondary graphic elements (like legends or scale bars), and suitable exchange formats all have to be observed. Moreover, a realistic perception of an animated sequence can only be achieved with a constant time scale – a conflict in the frequent case of unevenly spaced observation data. A necessary prediction of the state of the dynamic elements in-between the observations should primarily aim at realism and, only secondarily, at a nice graphic result.

Zusammenfassung: *Animation von Geodaten am Beispiel des Dresdner „Altai-GIS“.* Die klassische grafische Ausgabeform von GIS-Daten ist die statische Karte. Sollen jedoch Veränderungen von Geoobjekten in Raum und Zeit veranschaulicht werden, so ist eine animierte Darstellung überlegen. Außerdem lassen sich über dynamische Verfahren weitere Probleme grafischer Informationsübertragung reduzieren, indem man z.B. die Komplexität durch sequentielle Wiedergabe von Teildatenbeständen mindert.

Aus ausgewählten Daten des Dresdner „Altai-GIS“ wurden Animationen erzeugt. Diese sind in einen Film integriert, der den Rahmen zu methodischen Arbeiten lieferte und eine Projektdokumentation für ein breiteres Publikum darstellt. Animationen gingen in unterschiedlicher Form ein:

- non-temporal, (virtuelle Überflüge) und
- temporal (saisonale Schneedynamik).

Zur Realisierung der Animation mussten automatisierte Verfahren zur zielgerechten Datenaufbereitung gesucht und implementiert werden. Dabei waren verschiedenste Randbedingungen zu beachten, wie z.B.: Parameter des Wiedergabemediums, Art des Geometriemodells in der Animationssoftware, Verfahren der Grafikfusion zur Einblendung von Legende und Maßstäben, geeignete Austauschformate.

Ein exemplarisches Problem stellt die Erzeugung einer Animation aus Zeitreihen mit primär unregelmäßiger Beobachtungsfrequenz dar, denn nur ein konstantes Zeitinkrement in einer Animationssequenz birgt die Chance einer realitätsnahen Perzeption. Der somit notwendige Aufbau einer gleichabständigen Zeitreihe erfordert ein realitätsnahes Prozessmodell, für das ein Beispiel gegeben wird.

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1 Introduction

Ten years work on the German-Russian cooperation project „Altai-GIS“ have resulted in a large geodata base dedicated to support ecological monitoring and planning of the Siberian mountain system. The elaborate state of the GIS and its dynamic contents, which call for an equally dynamic presentation, were motivations for a film intending to address a wider audience. Nearly all visual material of the documentation „*The Russian Altai – New Approaches to Comprehend a Landscape*“ (LONDERSHAUSEN 2004) has been extracted from the GIS. Contents of the GIS suitable for „animated presentation“ were combined with static maps and scanned photographs in order to form a comprehensive visual source covering as well geographic features of the study area as specific Dresden research topics and results. A block-by-block organisation of the storyboard allows the appending of material without the need for future restructuring. This paper reports on the technical part of the creation of dynamic data bases and their transformation into „animated“ film sequences.

2 Animation of Geodata

2.1 *Definitions*

Animation is the synthetic creation of image sequences that appear to show metamorphosis or movement of objects or a mobile observer. Whereas video breaks up continuous motion into frames, animation works with independent pictures. The illusion of continuous movement results from *persistence of vision* meaning that an image is retained in the brain longer than it is actually registered on the retina (ATARI 1984). At a frame rate of above 24 images per second, a dynamic sequence will be perceived instead of individual frames (DRANSCH 1997, 2002). Animation is more than a slide show, since it operates with variable and stable image contents. The latter are perceptible links between consecutive frames.

2.2 *Animation – a Method of Visual Communication*

Compared to a static display, animation adds the dimension of time as a *„creative“* design variable. Dynamic components help to overcome difficulties in visual communication – the principal transmitter of geo-information:

Firstly, sequential presentation *reduces complexity*. Graphic problems caused by a small display and resolution restrictions become less frequent whilst simplified graphic contents help in not overstraining the capabilities of the spectator.

Secondly, *order of appearance, visual emphasis, and presentation time* of objects/object classes can be predetermined: a much stricter control of the information flow compared for instance to the individual's preference during an exploration of a map display. The antagonism caused by a *large spatial coverage and a display in full resolution* can be reduced, when a moving camera sequentially scans a landscape model, however, at the expense of total spatial synopsis. Limited capabilities of static media in documenting *variations of two- or three-dimensional objects* in time are the most apparent reasons for animation. Thereby, a visual model obtains a spatial and a time scale.

Animation modes have been labelled after the dynamic component (GERSMEHL 1990):

- Stage-and-Actor Animation, where objects vary in visibility and graphic design in front of a static background,
- Model-and-Camera Animation, where viewing or illumination parameters change in time, and
- Metamorphotic Animation, where ever-present objects vary in shape and extent in time.

Depending on the role of time, we can further separate into *temporal and non-temporal animation*. If the first makes use of forecast models or scenarios, we speak of a *predictive animation*. Furthermore, animations can be structured by checking for realism. If real-world processes are utilised, the fraction of observed or measured states (typically „key frames“ in a sequence) compared to simulated ones is crucial.

2.3 *Animation and GIS Features*

When relating animation methods to a GIS, several benefits become apparent:

A high thematic depth and a well-structured set of attributes are GIS features which inhibit simultaneous presentation. To clearly separate between semantic and graphic attributes is a generally accepted rule, which gives, on the other hand, flexibility in object selection and graphic symbolisation for each frame.

From imagery and terrain or surface models, flight-overs or walk-throughs with some degree of immersion can both be produced. A spatial overview can be achieved by watching a whole sequence, whereas areas of highest interest can be positioned close to the optical axis of the virtual camera. Pictorial (from imagery) and abstract elements (from map data) might be used simultaneously, but display of a wholly abstract animated landscape can also be informative.

There is no geodata without implicit or explicit *time reference*. Analytical tasks might even specifically rely on temporal change. Whenever ideas or formal models of the type, extent and distribution of dynamics are missing, an animated visualisation provides the most efficient access to an *exploration* of changes in terms of individual events and associated patterns. This, in return, encourages the development of new hypotheses and eventually new process models. Even if a process model exists in advance, its results may be proved against observations through animation.

3 The Dresden Altai-GIS

3.1 *Objectives and Contents*

The idea of animation should now be linked to the „Altai-GIS“: Spatial coverage is large, and themes are of a high diversity (see Tab. 1). Data structures comprise vector layers, grids, maps and images.

The GIS, in general, needs to lay-out an informative foundation for use in management of conservation. Use might also contribute to the idea of eco-tourism, which attempts to combine socio-economic improvement on site with a wider ecological awareness, education and experience (Prechtel & Buchroithner 2002).

The GIS is set up in two levels: The focus level, termed „Altai 100“, covers the Katun-Range in the Central Altai (about 10,000 km^2). An overview level – „Altai 1000“ – depicts the whole mountain system including its forelands (about 430,000 km^2). The name suffixes „100“ and „1000“ indicate levels of detail corresponding to map scales of 1 : 100,000 and 1 : 1,000,000, respectively. A more detailed discussion of contents, sources and methodology might be taken from Prechtel (2003), Prechtel & Buchroithner (2003), or the project homepage (Prechtel 2004).

3.2 *Contents Suiting Animated Presentation*

Animations in particular suggest themselves for two reasons:
On the one hand a basismaterial for *temporal animation* was at hand. A „snow cover“ series of „Altai 1000“ formed a strong base. Variations of glacier extents theoretically would provide another source. But low observation frequency and a weak empirical data base for a prediction of the ice dynamics in-between observations inhibit an animated model at present.

On the other hand, *non-temporal* Model-and-Camera animations can additionally promote the mental idea of the landscape character. They will incorporate DEMs and satellite imagery, land cover raster or vector layers, respectively.

4 Non-Temporal Animation – a Virtual Flight

4.1 *Pre-processing of the DEM*

Two raster DEMs („DEM500“ and „DEM100“ of Tab. 1) were used as principal

Tab. 1: Data of the Dresden Altai GIS (without imagery).

	Data Contents	**Data Level**			
		ALTAI 100: Areal Coverage 49° 40′ N – 50° 20′ N, 85° 30′ E – 87° 00′ E		**ALTAI 1000: Areal Coverage 48° 00 N – 53° 00′ N, 82° 00′ E – 93° 00′ E**	
Category	**Data Layer**	**Data Type**	**Elements**	**Data Type**	**Elements**
Relief	Digital Elevation Models	Raster	DHM 100, DHM 10, SRTM-3	Raster	DHM 500, SRTM-3
	Spot Elevations	Point		Point	
	Gauge Elevations	Point		Point	
	Hill Shading	Raster	Elevation tints & shading	Raster	elevation tints & shading
Geomorphology	Relief Facets	Polygon	type of neat lines	–	
	Macro-Relief Types	–		Polygon	
	Morphological Mountain Edge			Polygon	
Drainage	Rivers	Line		Line	Strahler Order
	Streams	Polygon		Polygon	
	Lakes	Polygon		Polygon	
	Watersheds/Catchments	Polygon		Polygon	
	Late Pleistozene Meltwater Lakes			Polygon	
Cryosphere	Glacier and Perennial Snow	Polygon		Polygon	
	Actual Glacier Fronts	Line	glaciers of Belukha massif 2001–2004	–	
	Ice Age Glacier Front	–		Polygon	
Land Cover	Forest, General	Raster, Polygon		Polygon	
	Forest, Classified	Raster, Polygon	deciduous, coniferous, mixed; krummholz	–	
	Meadows and Pastures, General	Raster, Polygon		Polygon	
	Meadows and Pastures, Classified	Raster, Polygon	marshy meadow, dry meadow, hill zone meadow, alpine meadow, mountain tundra	–	
	Void of Vegetation	Raster, Polygon	rock and scree	–	
Settlements	Settlements	Polygon		Point	function, population
	Streets	Line		–	
	Blocks	Polygon		–	
	Single Buildings, Sheds and Shelters	Point		–	
Communication	Roads and Pathes	Line	major road, minor road foot path	Line	major road, minor road foot path
	Railroads	–		Line	
Administration	State Borders	Line		Line	
	Administrative Borders			Polygon	
	National Park Borders	Polygon		Polygon	
Climatology	Meteo-Stations	–		Point	temperature and precipitation
	Snow Cover Time Series	–		Raster	1997, 1998
	NDVI time Series	–		Raster	1997, 1998, 1999
Geology	Faults	–		Line	
	Tectono-Stratigraphic Units	–		Polygon	
	Ore Ressources	–		Point	
Facilities	Conservation, General Administration	Point		–	
Documentation	Photo Points	Point		–	

geometry sources. The pre-processing of GIS-stored relief data for use in animations had to effectuate

- an optimum harmony between geometric and textural infomation,
- a complexity reduction of the DEM for subsequent rendering, and
- a migration to a 3D vector representation as an interface to the rendering software.

Even small geometric mismatches noticably diminish the quality of a virtual landscape: it is crucial, that principal relief structures do well coincide with the drainage or shade patterns of the image texture. In-house software tools particularily helped in improving the original DEMs to show, for instance, flat lake surfaces and continuous gradients in runoff direction of the rivers.

Softimage|3D in the version 3.9.1 was chosen for the production of the animation (with a friendly assistance of the staff of the Dresden University Computing Centre). Strict limits to the maximum number of meshes of its internal geometry model called for a DEM thinning without a violation of the above cited integrity demands. Arc/Info TIN generation allows a controlled limiting of the number of meshes. The raster DEMs constituted the bulk of data. A forced introduction of selected spot elevations, break and form lines resulted in edge geometries which finally adapted well to the prominent landscape structures. Depending on the predefined camera path, TINs of varying geometric detail could be produced and amalgamated, in order to arrive at smaller triangles along the camera axis and a slightly thinned fabric towards the margins.

Two final models have been tailored to a Landsat ETM mosaic of 66,000 km^2 which is covering major parts of the Altai Republic. A third was created for a low altitude flight and panoramic panning within the inner study area. A geometry transfer to Softimage|3D could be realised through the universal VRML code.

4.2 *Realisation of the Animation*

Three-dimensional landscape visualisations consist of a geometry which emulates the shape of terrain, and a texture overlay which contributes to complexity and visual realism of a scene (Suter 1997).

After importing the geometry to Softimage|3D, edges between the triangular planes with angles below 60° were smoothed. All elevation entries were vertically exaggerated by 1.5 to strengthen the visual relief impression.

Landsat ETM bands 3,2 and 1 from two scenes were transferred to Softimage|3D as RGB-TIFF data after radiometric corrections for shadow zones and light haze. Optical surface properties were set matt in order not to conflict with the illumination at date and time of image take. Additionally, a dome with a skylight-like brightness distribution and synthetic clouds was designed around as a model atmosphere.

Flight animations deal with variation of observer position and view angle relative to a model landscape. Key frames are defined by camera co-ordinates and focus, whereas the motion is interpolated along a splined path for in-between frames. Obviously, one makes sure that model edges are invisible, in order to establish a natural horizon. For the main sequence, an S-shaped path from the lowlands to the highest mountains was defined. A small camera icon simultaneously scans a sketch map at the display edge and helps to localise the actually portrayed section.

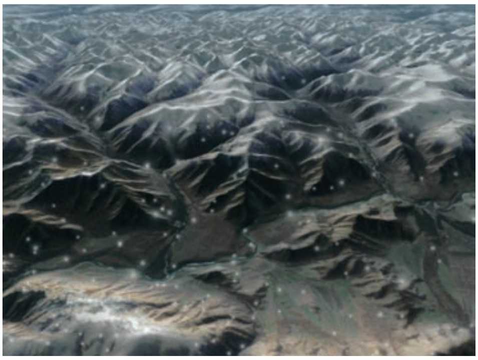

Fig. 1: The virtual Altai during winterly snowfall.

A second sequence showing a winter landscape works with a fixed camera position and a panoramic pan. Falling snow was created with Softimage|Particle to thematically lead over to the film topic of snow cover change (Fig. 1).

5 Temporal Animation – Seasonal Snow Dynamics

5.1 *Snow Cover from AVHRR-14 Data*

Research on snow cover dynamics has initially been funded by a NATO Collaborative Linkage Grant. We had picked a two-year observation period (1997/98) for the existence of high-resolution reference imagery. The study has been based upon AVHRR-14 images.

A series of snow masks became the principal data source for the animation. However, before proceeding to the animation task, principles of the snow classification (Höppner & Prechtel 2002) shall be mentioned.

A pre-selection of AVHRR level 1B data from NOAA's SatelliteActiveArchive came first. Almost 1000 archived scenes of 1997/98 partly or fully cover the target area. This vast number had to be rigidly filtered. Suitability meant:

- Study area located within a 35° viewing cone (to limit resolution degradation and relief displacements),
- cloud coverage low or – if present – outside of major snow fields,
- high number of observations at the peak of snow dynamics.

5.2 *Radiometric Preprocessing and Rectification*

Only 42 scenes could be retained. Sophisticated image applications need a conversion of greyvalues into reflectance or brightness temperature. *Data calibration* at data user's side means post-flight calibration, and mainly corrects for insolation, sensor degradation and thermal attenuation effects.

The planimetric accuracy of geometric *rectification* using ephemeris data of the header files is in a range of 0.05°–0.1° (Cracknell 1997), a corresponding altitude variance of an extracted snowline might be 2000 m and more in the Altai's mountainous relief: substantial geometric improvement had to be achieved. A cloud-free summer scene with high radiometric dynamics and a minimum snow has been identified as the master image. Its primary rectification by ephimeris data has then been refined by manually positioned Ground Control Points (GCPs). GCPs at shorelines – relatively unambiguous features in most AVHRR data – could be found in a reasonable distribution, so RMS residuals obtained from a polynomial transformation immediately dropped to around one pixel. The rectified master scene then served as a uniform reference for image-to-image registration, a method that delivers more homologue points than an image-to-map search. For a final geometric fine-tuning of all co-registered scenes, an automated step was finally added. It compares image shorelines to reference shorelines taken from maps, and iteratively produces a mutual best fit. A gradient descent method is applied to the rastered reference model and serves for a global geometric rating (Prechtel & Bringmann 1998). The program improves the geometric fit by allowing small global shift, rotation or rescaling of the image, depending upon the best possible improvement compared to the preceding step.

5.3 *Snow Classification and Interpolation under Clouds*

Now the classification proper had to be carried out. After an evaluation of studies addressing snow extraction from AVHRR, a method developed at Bern University has been chosen (Voigt et al. 1999). The author describes a pixel-based, hierarchical method using spectral or bi-spectral thresholds. A basic set of input values, derived from our own imagery and from exterior findings, gave an introduction point for a raw classification, which had then to be evaluated.

Thereafter if needed, threshold alterations were applied until the results were in good accordance with a careful visual interpretation. Control aids were given by: the „snow-vegetation-view“ (AVHRR-1, NDVI and reflective part of AVHRR-3), and the „snow-cloud-view“ (AVHRR-1, AVHRR-2 and the reflective part of AVHRR-3). Besides a snow mask, a cloud mask was generated, which leads over to the remaining problem of classification gaps under small cloud clusters. Our solution assumes that the snow line is the best predictable measurand, when analysed per „Snow Cover Unit“ (SCU), meaning a snow segmentation by terrain inclination and aspect. Stratified by SCUs, all DEM cells bordering snow clusters of the classification have been triangulated. Then, all locations above the predicted snow line within the no-data islands could be added to the snow class.

In the context of the animation, these „refined“ observations could now form key frames. But to arrive at an evenly spaced time series, a methodology still required to be found which was, in the same time, both simple and also close to the processes of snow accumulation and depletion. The latter demand excludes methods such as morphing.

5.4 *From Unevenly Spaced to Daily Snow Assessments*

The interpolation algorithm takes into account that the extent of snow mostly varies with terrain altitude. Snow melt usually starts in the lowlands and valleys to gradually migrate uphill whereas fresh snow cover begins to build up in higher elevation first to eventually migrate downhill. More complicated climatic processes of a local scale (luff-lee effects, snow drift, insolation, etc.) had obviously to be disregarded in a large-area presentation (100,000 km^2).

Firstly, two consecutive AVHRR classifications were analysed for spatial differences. „Change of snow“ pixels were then clustered (using an 8-cell neighbourhood). This makes it possible to subdivide clusters of spatial increase or decrease into a number of evenly-spaced altitude intervals and their member cells, respectively, which can sequentially be filled or freed of snow according to the number of days between two consecutive observations. However, discontinuous precipitation behaviour (e.g. periods of stagnant snow cover, times of fast melting or spreading of fresh snow) means that such a simulation appears rather unrealistic. Aiming for higher realism meant incorporating supplementary meteorological data. Daily precipitation measurements in a suitable spatial distribution were and will not be available due to a lack of stations within the vast uninhabitated parts of the Altai. But, alternatively, the „Northern Hemisphere Snow and Ice Cover Chart“ by NOAA is a source that shows snow/ice extents on a daily base, even if aggregated to a poor spatial cell resolution of around 25 km × 25 km. Therefore it cannot replace the original observations (500 m × 500 m-cells), but appears to be useful as a temporal predictor of variation. Some preparatory processing was required in order to advance its integration:

- conversion to binary snow mask
- projection change and vectorisation to harmonise with the „Altai 1000“ GIS standards.

Now, the chart was toughened up to predict the temporal and – in a lower resolution – spatial behaviour between two AVHRR observations. As a result, the altitude-dependent interpolation lost its schematic and linear behaviour. Variation of each observed snow cluster could be initiated or terminated in a reaction to the state shown in the „coarse“ daily Snow and Ice Cover Chart. The simulated snow fall and snow melt now realistically stagnates or speeds up. In spite of good correlation between high- and low-resolution snow cover from these independent sources, some contradictional patterns emerged. Therefore, dynamic clusters in the classification without indication in the Snow and Ice Cover Chart had to be processed according to the simple linear altitude step principle explained above.

Following these rules, daily snow masks from January 12, 1997 to December 16, 1998 could be produced. The few days from 1st of January, 1997 to the first observation day as well as the missing days from the last observation to the end of 1998 were simply added by copies of the closest frame. This should be a passable solution because of the small variation in high-winter snow.

5.5 *Realisation of the Animation*

The „DEM500“ geometry could be used as in the case of the flight animation. Synthetic land cover textures from „Altai 1000“ land cover (Tab. 1) serve as background for the presentation. This will be called a Stage-and-Actor Animation (comp. chap. 2.2): the stage is the landscape portrayed by geometry and landcover texture; the actor is the snow dynamically screening parts of the underlying texture.

By comparison to the above, whilst the landscape state is changing, the virtual camera remains stable. The original 730 masks had to be duplicated in order to reduce the animation speed to a more suitable pace for the perceptive abilities of the spectator (58.4 seconds or 1460 frames). They are all treated as individual frames, whereas „black“ pixels indicate transparency. Additional shading from an infinite light source enhances the relations between relief and snow. A diagram in the corner of the display illustrates the temporal progression and dynamically informs about the actual percentage of snow covered land. Technically, it becomes a second small animation over the same time range. Axes and graphs with markers at each classification date (key frame) are stable, whilst the pointer and the filling below the graph are following the snow cover frames (Figs. 2 and 3).

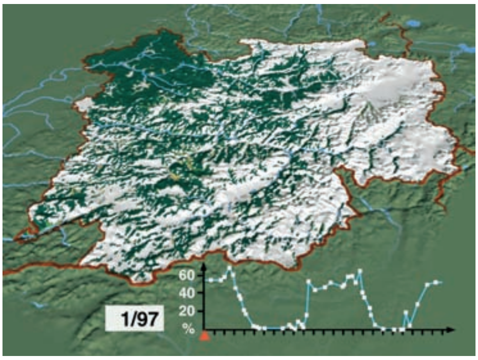

Fig. 2: Frame showing high-winter snow cover (January, 1997).

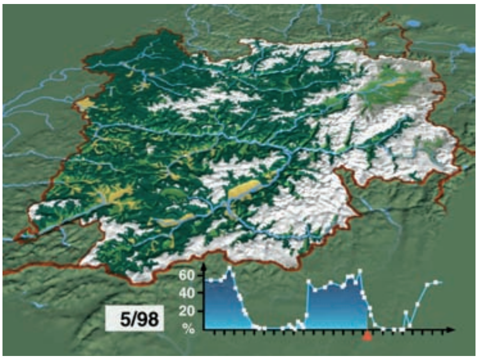

Fig. 3: Frame showing a situation during snow melt (May, 1998).

6 Demand for Further Research

The film clearly shows the advantages of dynamic geodata presentation. Some principal deficiencies, within the process from concept to technical realisation, motivate further research and can be grouped into the categories:

- theory of visual communication,
- display techniques, and
- production techniques.

Refering to *communication theory*, little is known about average perception capabilities of different user groups. Unfortunately there is no clear guidance on the limits of visual comprehension in relation to complexity of visual geo-information within a dynamic sequence. Many potential problems are inherent within the snow cover sequence: patterns of various size change in different relative positions and velocities. The dynamic time scale also has to be kept in view. At the same time, the presentation speed is rather fixed because of the missing data for additional frames, and the minimum necessary frame rate (see 2.1). As a result, an eventually overstrained user may only react by repeating a whole sequence or by stopping it at points he wishes to focus upon. It is noted that a sound track might have alternatively been used for the time relation in order to simplify the visual canal.

This leads over to *display techniques*. Standard control functions of for instance a DVD player are limited. Flexible zoom, speed alterations, and cuemarks would give higher flexibility, especially for work with educational or scientific material. As a low-effort response to the problem, we created a selection menu which already allows the starting of predefined sequences by a mouse click.

Geodata display on electronic devices brings a lot more difficulties: a small display area with limited resolution, and device-dependent colour reproduction are obvious problems. Less known is the impossibility to equally fulfil the display requirements of both a computer monitor and a TV set (MÄUSL 1995). The latter not only suffers from even lower resolution compared to PC monitors, but also an uneven side-ratio of the pixels. Computer-generated frames of 768 by 576 pixels have to be resampled to 720 by 576 pixels to show correct dimensions on a television. Alternating „writing cycles" between even and odd lines of the image matrix in a frequency of 50 Hz (PAL standard) cause flickering along horizontal lines with static image signals. This is clearly less of a problem for filmed sequences but more noticable in animations with a static camera.

Production techniques. Quite an efficient automated data flow from GIS-stored geodata to an animation software has already been achieved, but further improvements could both smooth it and speed it up. Examples can be given: for use in animations, the level of detail (LOD) of a DEM should react to camera perspectives. Built-in LOD steering, of software at hand, performed unsatisfactorily. A „work-around" using full-sized TINs with different tolerances therefore became necessary. Cutting-lines parallel to the flight path were generated, and, finally, a new TIN mosaic was assembled. A smarter solution would perform thinning within one step, using a distance-dependent elevation tolerance function. Texture handling could also be improved. If texture means a colour-coded area mosaic, the work-flow is quite simple: tabular data relates polygon attributes of a coverage to codes, which will then become cell values of a raster representation with size and resolution both set to the animation standards. A further table can now connect the cell values to the desired colour scheme, and the RGB-image matrix can be exported using a supported format. However, if object properties are displayed by complex textures (e.g. a forest by individual trees) or with varying visual properties, no smooth interface exists to the „animation world". If dynamic legends are produced, some user interaction is also required. As stated above, these are handled as independent sequences in the software, and, only within a second step, become fused with the other image contents.

This article could only select a few aspects from a wide field of potential further research. Effort in improving dynamic geodata presentations will be fully justified. Limitations by hardware performance, software functionality and data availability are currently small and will further decrease in future.

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