

# SMOOTH TRANSITION BETWEEN 2D AND 3D DIGITAL ATLAS VISUALIZATION USING COMPUTER GAME TECHNOLOGY

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## ABSTRACT:

3D visualization is acknowledged as being an important and useful aspect of digital atlases and has been consequently implemented in the last years. Nevertheless, there is still a potential for significant improvements. One challenging research topic is the seamless integration of 2D and 3D navigation possibilities. Recently, computer game technology has been recognized as an interesting research field also for 3D cartography. In particular, computer game technology offers the possibility to generate 3D virtual terrains navigable in real time and at low costs.

The Institute of Cartography of ETH Zurich is currently involved in the development of the ATLAS OF SWITZERLAND 3.0 and is a consortium member in the EU FP7 project 80 Days – around an inspiring virtual learning world in eighty days.

Following the specific interests of the two projects, it has been decided to implement Atlexicon, an elementary digital atlas based on computer game technology. This application allows to freely explore thematic raster maps in real time. Simultaneously, additional attribute information is shown through specifically designed 3D symbols. By changing the viewing angle of the camera used for rendering, it is possible to shift from 2D to 3D visualization without loading time interruptions or abrupt modality switches.

By implementing Atlexicon we achieved two different goals: On the one side the possibility of re-using game-assets and learning resources for the realization of digital educational products can be shown. Due to the currently high level of costs for developing immersive digital educational products, its reduction through re-utilization of resources and assets will facilitate the employment of digital games for educational purposes. On the other side the adoption of computer game technology for cartographic purposes can be tested. This allows the formulation of considerations and recommendations for the future use of this technology in the development of 3D digital atlases.

## 1. INTRODUCTION

At present, virtual globes with real time 3D exploration possibilities such as Google Earth or NASA World Wind are known and used by a large number of users. Aspects such as attractiveness, versatility, facility of use and licence fee free use have already been identified by Marty, Cron, Bär, Häberling, & Hurni (2009) as reasons for their success. Köbben & Graham (2009) suggest that the users of Virtual Globes, Geodata Infrastructures (GDIs) and (digital) National Atlases are becoming more and more alike in particular due to the similarity in the techniques and tools (web-based clients) used to access the three different worlds. Building on this assumption it is legitimate to assume that users of National Atlases will expect more and more from these products an experience similar to that of Virtual Globes. It is therefore possible to argue that National Atlas user would like to experience what Sheppard & Cizek (2008) summarize as factors inducing the appeal of Virtual Globes, namely “the realism, the sensation of flying towards or over the earth [...] and the sense of their own control over the medium and data” (p. 2106).

At the same time 3D computer games in first or third person view with the possibility to freely navigate a 3D virtual terrain are also characterized by high popularity. It is possible to expect, that also this kind of technology can partly contribute to an increased expectation or at least influence the customs and habits of the modern beneficiaries of geographic and cartographic material. Köbben & Graham (2009) present a first tentative to merge these different worlds and to increase the navigation functionalities of National Atlases and GDIs by trying to integrate the Dutch National Atlas, the Dutch National Geodata Infrastructure and Google Earth.

In this paper we want to present the results of a first investigation work on the potential of computer game rendering engines with the purpose of enhancing the user experience with digital National Atlas. By rendering geographic information and cartographic material with computer game technology it is possible among other aspects to increase the degree of freedom in the data exploration and to obtain a smooth switch from a 3D to a 2D visualization of the same information.

## 2. BACKGROUND

### 2.1 Atlas of Switzerland 3.0

The ATLAS OF SWITZERLAND 3.0 (AoS 3.0) is a joint project of the Institute of Cartography of ETH Zurich, the ETH board, the Swiss federal statistical office and swisstopo. As a national atlas, AoS 3.0 contains a broad range of thematic issues covering the entire country. The basic concept of the atlas aims at propagating adaptive, high-quality maps, interactive tools and the integration of 2D and 3D maps. Totally more than 2000 map themes are included divided in the seven domains Nature & Environment, Society, Economy, State & Politics, Energy, Traffic and Communication. Several of these topics are also treated in a European context (Sieber, Geithövel & Humi 2009).

Besides conventional map navigation (pan, zoom-in, zoom-out), AoS 3.0 offers an index of place names with automatic centering of the map according to the clicked name as well as the possibility to visualize changes in time and space in form of an animation. Additional 2D functionalities are: (1) the possibility to virtually query all objects of thematic and base map layers; (2) the possibility to compare individual map objects (e.g. different communes) through colored bars representing the thematic value of the clicked element; (3) the analysis tool allowing individual generation of specific cartographic representation for analysis and visualization purposes (Sieber & Huber 2007).

In the 3D section of AoS 3.0 three different views are provided: block-diagrams, panoramas and prism maps. In all the three cases a ray-tracing method is used by the rendering engine. As ray-tracing with high-resolution data is rather slow, a small preview image is integral part of the interface. Analytical modules, exclusively based on the terrain data, are included in the 3D section. Hypsography, slope, aspect, fog and lighting can be activated according to the desired visual analysis of the 3D scene. Overlay modules, based on various 2D data allow superimposing topographic information such as lakes, urban areas or glaciers on the 3D surface. The overlay of a satellite map and the integration of sky features like clouds, sun, moon and stars, and planets makes photorealistic 3D maps possible (Sieber & Huber 2007).

### 2.2 80Days – Around an Inspiring Virtual Learning World in Eighty Days

*80Days – Around an inspiring virtual learning world in eighty days* is an interdisciplinary research project funded by the European Union as part of the seventh framework research program (FP7) and is concerned with theories, methodologies and technologies for game-based learning. The main goal of the consortium involved in the project is to elaborate techniques and methodologies for developing successful digital educational games (DEGs). This is demonstrated by the development of a geography game prototype.

Beside the investigation of the possibilities for adaptive content submission from a psycho-pedagogical point of view, one of the foci of the research project is the tentative to develop a framework enabling the reduction of DEGs' development costs. Concretely one of the approaches adopted

by the 80Days consortium is the combined utilization of geographic datasets and computer game rendering engines in order to semi-automatically generate 3D navigable virtual terrains representing reality as described by the input data. In a first project phase an SRTM digital elevation model (DEM) and a MODIS satellite image have been used for the generation of a 3D virtual terrain of Western and Central Europe. The virtual terrain has been used as stage for flying missions that constituted the main part of the DEG's first demonstrator. By flying over a virtual terrain corresponding to the real situation the user of the DEG is able to acquire geographic knowledge of the European continent from a new and appealing point of view. The realization of the virtual terrain with computer game technology allowed not only a new type of navigation compared to traditional 3D digital atlases but also the embedding of the flight experience into specifically designed learning situations. In a second phase of the 80Days project the virtual terrain has been enhanced. This has been possible on one side thanks to the adoption of Landsat imagery with better spatial resolution. On the other side the inclusion of 3D objects resulted in an improved and more appealing scene. Finally, in a third phase of the project the framework developed for the semi-automatic terrain generation with geographic datasets has been used for a prototype implementation of a 3D navigable digital atlas named Atlexicon. By rendering thematic maps instead of satellite imagery and by adopting 3D thematic symbols instead of real objects a new and different educational product has been obtained using the same technology as in the previous phases. The resource integration methodology developed in the 80Days project allows the reduction of DEG's development costs and time in a twofold manner. On the one side the virtual terrain generation approach can be easily re-adopted for other projects. On the other side 80Days shows the possibility to semi-automatically generate a 3D virtual environment using freely available geographic data not restricted by terms of use or licenses.

## 3. RENDERING A 3D DIGITAL ATLAS WITH COMPUTER GAME TECHNOLOGY

### 3.1 Previous Research

The potential of 3D virtual environments as a tool for communication of spatial content was already discussed and motivated in the first half of this decade and has been extensively described later on by Katterfeld, Paelke & Sester (2007). In particular, in the work of Katterfeld et al. (2007), the direct presentation of the spatial information, its immediate visibility and the possibility to directly explore it by virtually navigating it are listed as some of the interesting benefits of a virtual environment. In addition to that in the same paper virtual environments are proposed as tools to be used in education and e-learning. According to the authors the utilization of virtual environments represents a trend towards the reality-like teaching of geoscientific phenomena.

Other potentially very interesting tools to be adopted in education are educational computer games. Through the utilization of DEGs, learning can be made engaging, inspiring and presumably effective. This idea is described in detail in

the paper of Law & Kickmeier-Rust (2008) and constitutes the fundamental principle of the 80Days research project.

A logic conclusion of these two different considerations is the further investigation of virtual terrains as part of digital educational games. The realization of a virtual environment as part of a DEG for teaching geographic contents allows the exploration of the potential of game engines for terrain rendering purposes. This is also partly addressed by the 80Days project. This kind of approach has already been recognized as interesting by Trenholme & Smith (2009) who attest to computer game engines the capability of generating “inexpensive state-of-the-art 3D virtual worlds that can be customized to experimental requirements in a short amount of time without extensive programming” (pp.181-182).

One interesting work in this field has been carried out by the Centre for Advanced Spatial Analysis, University College London, who made a reconstruction of the city of London by using 3D GIS data and CAD models using Cry Engine for visualizing it (Evans, Hudson-Smith, & Batty 2006). Cry Engine is one of the most powerful game engines developed by Crytek used in Far Cry game. Within the 80Days project an intensive analysis of game engines to be adopted had been conducted, choosing between commercial, open source and web-based ones. The requirement of cost effectiveness, fundamental in the project, has led the consortium to opt for the Nebula 2 game engine, an open source solution that guarantees good graphic quality and performances without the need to buy an expensive license, as in the case of commercial engines.

The employment of 3D in cartography is nothing new. Concepts and visions for 2D and 3D navigation in atlases have been for instance discussed by Huber & Sieber (2001) and preliminary design principles for topographical 3D maps have been derived by Häberling (2003). Even though 3D cartographic representations suffer from perspective distortions and occasionally obscured objects, they may be seen as an intermediate step between 2D maps and reality (Jobst & Germanchis 2007). Particularly interesting for the work presented in this paper are the considerations about the features of standalone 3D presentations techniques such as computer game engines: lighting, shadows, navigation or different texturing methods are identified as useful features for a better communication of spatial information (Jobst & Germanchis, 2007).

### 3.2 Goals

Based on the presented consideration we decided to test the utilization of 3D computer game technology for the rendering of a virtual environment based on cartographic atlas material. On the one side the purpose of this experiment is to show the possibility to create a new digital educational product based on already existing technology and material and therefore to tackle the development cost issue of DEGs mentioned by Law & Kickmeier-Rust (2008). On the other side the game technology and in particular the possibility to easily manipulate the virtual camera allow the implementation of the smooth shift between 2D and 3D visualization using a single set of shared navigation tools proposed by Huber & Sieber (2001). From a more general point of view we want to

investigate if the presented approach can lead to an increased appealing of 3D atlas representations and at the same time formulate some considerations for the use of this technology in the development of 3D digital atlases.

## 4. THE PROPOSED APPROACH

In order to achieve the goals described in the previous section we developed an approach consisting in the utilization of two different game engines for the 3D rendering of thematic cartographic maps. The first test is performed based on the research work carried out in the first phase of the 80Days project. In the first 80Days demonstrator a virtual environment has been obtained with the Nebula 2 engine (<http://sourceforge.net/projects/nebuladevice/>) and has been used as a stage for different flying micro-missions. By removing the additional game elements (spaceship, non-player character, flight-speed indicator ...) and the gameplay features from the game engine it is possible to realize Atlexicon, the first of the two tools for the generation of cartographic virtual environments. By replacing satellite images with thematic maps and trees and buildings with iconic 3D symbols (cubes) it is possible to realize a prototypic 3D navigable digital Atlas using the same technology already adopted in 80Days. This tool allows the generation of different 3D surfaces from thematic maps and is able to draw 3D symbols for the display of additional information

In order to overcome some constraints related to the utilization of a specific engine the presented approach includes a second test with a different game engine. In particular, the second test provides alternatives to limitations such as difficult rendering enhancement, lack of in-depth documentation and no longer available commercial tools for converting 3D objects. For the development of Terrain Viewer, the second tool for rendering thematic virtual surfaces, the open source game engine Irrlicht Engine (<http://irrlicht.sourceforge.net/>) has been chosen. The main advantages of Irrlicht Engine compared to Nebula 2 are: better documentation, active community and straight forward source code, multi-platform, simple scene management, easy 2D rendering, support for most common 3D object formats and easier management of multiple textures.

With the adoption of the described approach two different tools can be obtained allowing free navigation of thematic 3D surfaces. In particular, thanks to the possibility to change the viewing angle of the camera a smooth transition between 2D and 3D visualization is possible. The obtained results can be compared with the rendering of similar thematic maps achievable through the AoS 3.0 in order to identify advantages, disadvantages, potential and limitations of the different results.

## 5. PROCEDURE

For the selection of the topics to be represented as navigable virtual surfaces in the first demonstrative version of Atlexicon different criteria have been considered. In order to allow an easy comparison of the AoS 3.0 and Atlexicon a thematic

map already available in the atlas has been chosen. The mean annual precipitation map has been selected mainly due to the raster format of the original data and the geographic extent of the map covering whole Europe. The same thematic map has been used also for the rendering of a smaller region with a higher level of detail (Switzerland). On the other side it has been decided to include a map of the EU-membership of the different European countries in order to maintain a certain link to the previous work done in the 80Days project (EU-membership of the different countries is one of the skills conveyed through the main demonstrator). This second map has been manually created in GIS based on countries shapefile data. The resulting map simply shows a political map of Europe with different color codes for EU-member and non-EU member countries. In order to investigate the possibilities to include 3D symbols for the representation of additional thematic information in the navigable atlas, additional geographic data have been selected. Yearly precipitation maps are enhanced with cubes of varying dimensions and colors representing the specific amount of precipitation for single locations. In the EU-membership map the same kind of symbols (with different colors and dimensions) indicates the number of inhabitants at selected locations. As elevation data, necessary for modeling the terrain, a SRTM DEM from NASA has been used in all the three cases (yearly precipitation for whole Europe and only for Switzerland, EU-membership for Europe). The higher level of detail of the smaller Swiss terrain has been achieved just by projecting a texture with higher spatial resolution on a terrain with low level of detail.

Before submitting the selected textures to the game engines, the former ones have been slightly modified in a GIS. After the GIS processing the thematic maps have been exported as raster images and submitted together with the elevation data as input to a specifically written tool. This tool converted the data into a format useable by the game engine. In particular, thanks to the GIS manipulation it has been possible to enhance the selected thematic maps with additional information from geographic vector datasets. Rivers, lakes and boundaries layers have been added in the GIS and rasterized through the export of the visible scene.

Finally the three exported textures and the elevation data have been submitted to the two different rendering engines Nebula 2 and Irrlicht for the generation of the navigable 3D virtual environments.

## 6. RESULTS

The described approach resulted in two different prototypes allowing the generation of freely navigable 3D representation of thematic surfaces. The obtained results are presented in Figure 1 and compared with a 3D representation available in the AoS 3.0. As it is possible to see in the two top images of Figure 1 Atlexicon allows a representation of thematic maps similar to those in traditional digital atlases. 3D symbols with proportional sizes and coded color shades provide more thematic information about topics related to the content of the rendered thematic map. The meaning of symbols' color and dimensions are explained in the legend. In Atlexicon it is

possible to zoom in and out (between a minimal and maximal zoom level defined in the implementation phase), to pan, and to rotate the rendered thematic surface through the keyboard. Using the keyboard it is also possible to turn on and off some GUI elements such as the inset map or the legend. Additionally, 3D symbols can also be turned on and off. The legend automatically reacts to this choice and shows/hides the corresponding symbols accordingly. This atlas prototype realized with the Nebula 2 engine also allows the collection of additional information and material about certain previously defined locations when an area in proximity of these locations is visualized. By zooming and panning close enough to the light cones visible in the top left image of Figure 1 the system reacts with a message saying that additional information is available for this location. By pressing 'I' on the keyboard it is then possible to see a short summary of some statistical data as well as corresponding pictures and maps.

The two Atlexicon images show two different thematic environments implemented in the prototype. The left image represents the EU-membership of European countries at a continental level. The example almost corresponds to the lowest possible level of zoom for the showed map while the right one shows the rendering of a mean annual precipitation map for a part of Switzerland. The differences between the two terrains consist apart from the topic in the extent of the virtual environment and in the spatial resolution of the adopted texture. The two aspects are strictly interconnected due to the limited amount of pixels manageable by the developed prototype. Smaller pixel dimensions are only possible at the expense of the rendered extent. The political map of Europe allows the exploration of the general situation only at a small scale. The Swiss terrain can be used for observing smaller details and local differences at bigger scales. Due to the better spatial resolution for the Swiss precipitation map it has been possible to include smaller linear elements such as lakes or rivers. However the most evident difference is probably the higher level of detail of the terrain. It is important to note that this higher level is achieved rather by better texture than better elevation data. The underlying shape of the terrain is in both cases the same.

The other important difference between the two Atlexicon images illustrates one of the main features of the prototype, namely the possibility to adopt different view angles. The left image shows a perspective view of the terrain. This allows the visualization of the terrain's shape and of areas lying far away from the point of observation. By turning downwards the viewing camera it is possible to obtain (as showed in the right images) a top-down visualization of the thematic information. Ideally this top-down view should represent a classic 2D map visualization. Unfortunately in this prototype the necessary change of the rendering from central to orthogonal perspective could not be realized. This can be in particular observed by the visibility of the lateral sides of the cube in the top-left corner of the second Atlexicon image. Important is the fact, that this change from perspective to top-down view does not require any additional loading time or interruption of the navigation flow.

Terrain Viewer, the prototype developed using the Irrlicht Engine is very similar to the Atlexicon prototype. Also, with

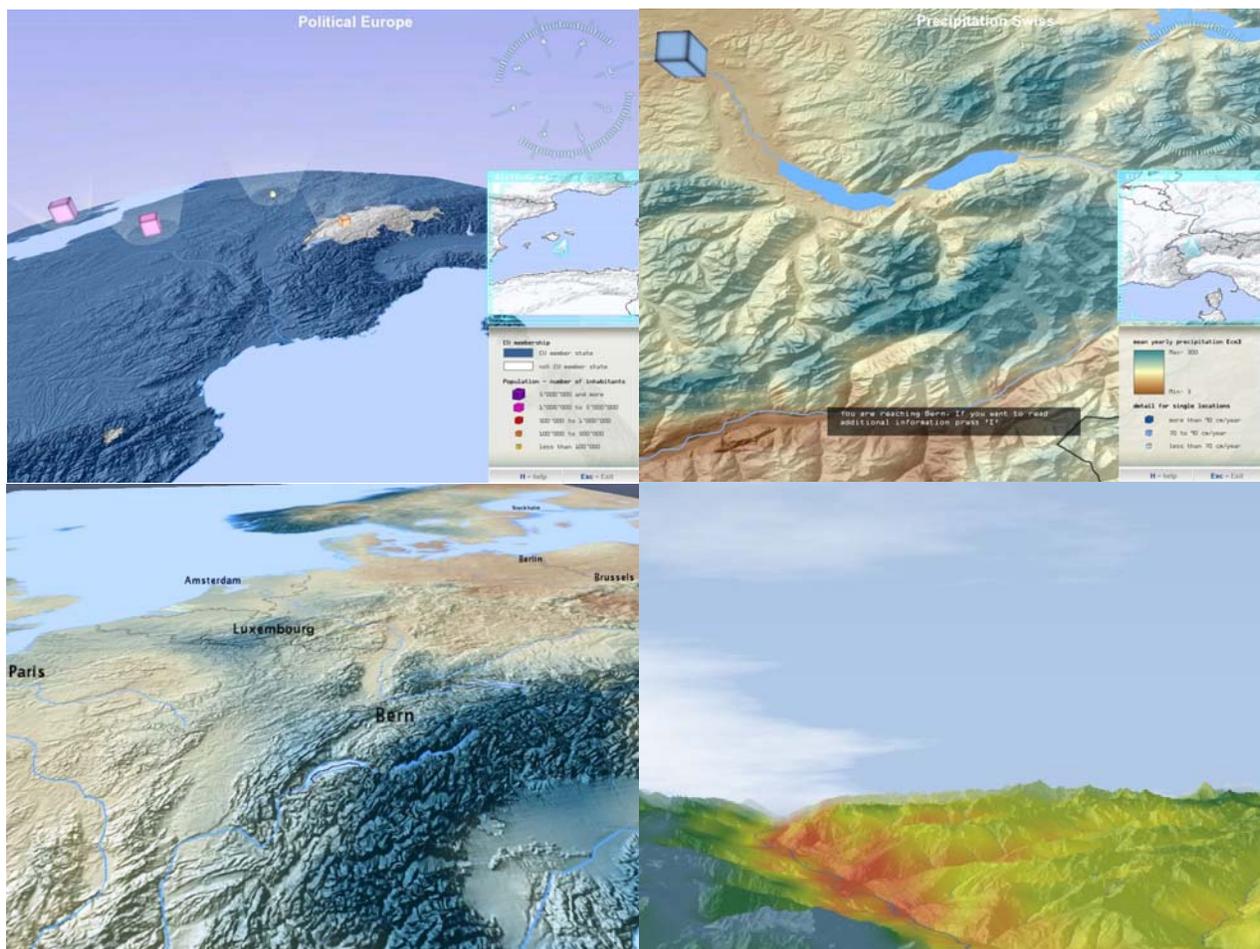


Figure 1: Screenshots from the two implemented Prototypes Atlexicon and Terrain Viewer as well as from AoS 3.0. Top left a perspective view in Atlexicon of a political map. Then clockwise: a top-down view in Atlexicon of the precipitation map with better level of detail, perspective view of Europe in Terrain viewer and panorama of a precipitation map generated with AoS 3.0

## 7. DISCUSSION

Terrain Viewer, it is possible to zoom, pan, and rotate the terrain as well as turning on and off objects and GUI elements. The principal innovations of this second prototype compared to the first one are constituted by the possibility to switch from a texture to another without having to reload the terrain (if the extent stays the same) and by the 3D labeling of point objects. As it is possible to see in the bottom-left part of Figure 1 the Irrlicht Engine allows the generation of 3D labels for the description of particular features. An important characteristic of this functionality is the automatic rotation of the label in order to match the current position of the camera.

By turning the camera around a labeled point, the label will also rotate in order to be always readable. The possibility to turn on and off textures available in this second prototype allows for instance the hypothetic customization of a rendered terrain with additional information such as additional base map layers (rivers and lakes, roads, boundaries, etc.).

A visual comparison of the screenshots of the two prototypes and AoS 3.0, as presented in Figure 1, does not show important differences. With the developed prototypes it is possible to render a thematic map in 3D similarly to what is already possible with AoS 3.0.

The principal innovation brought by the utilization of game engines for the rendering of thematic 3D virtual environments can only be experienced by the utilization of the developed prototypes and is constituted by the enhanced navigation possibilities. In the AoS 3.0 the 3D scene has to be reloaded after setting the parameters such as the point of observation, the extent of the rendered area or the distance from the terrain. In Atlexicon and Terrain Viewer it is possible to dynamically change such parameters without having to wait for the recalculation of the resulting picture. The resulting seamless spatial navigation provides the sensation of a virtual real-time fly over the terrain. Thanks to the manipulation through keyboard and mouse the sense of control over the

medium is quite elevated. On the other side some important functionalities typical for digital atlases are not present in the prototypes. An example is the missing possibility to directly query the system for getting the exact value of the represented information at a certain point (e.g. through mouseover functionalities). Other aspects such as the limitation of the source data dimensions manageable by the engines or the central projection of the camera have not been sufficiently tackled at the moment.

Nevertheless the prototypes presented in this paper look promising. In particular the convergence of the two apparently separated worlds of digital atlases and digital (educational) games shows interesting possible developments. The possibility to create a basic version of a 3D digital atlas with computer game technology suggests on the one side the inclusion of such a tool in digital education products in order to enhance the learning content and the appealing. On the other side the fusion of the two technologies could also lead to the enhancement of digital atlases with gaming and or more interesting navigation functionalities.

## 8. CONCLUSION

This paper presented the results of a first tentative of merging two different research fields. Research trends in the utilization of computer game technology for the generation of virtual environments and new developments in the 3D visualization of atlas content suggested the implementation of two prototypes for rendering 3D thematic information using computer game engines.

Thanks to the possibility to explore thematic information in a flight-similar manner, the developed prototypes allow a new kind of spatial navigation of 3D atlas content. In particular the real time rendering of the scene allows a smooth transition between top-down and perspective view of the data. This can also be compared with an interruption-free switch between 2D and 3D cartographic visualization. A more accurate investigation of camera projections' possibilities is necessary. In particular the orthogonal projection capabilities of game engine should be further tested. Nevertheless this functionality appears particularly interesting in the field of digital atlases.

Since the focus has been put on navigation, other typical atlas functions are lacking in the two prototypes described in this paper. At the same time other technical limitations such as the fixed maximal file dimensions of the rendered textures appears momentarily as a non-negligible drawback. Both mentioned aspects appear however as not being unsolvable. This fact, and the positive feeling generated by the new navigation possibilities let us suggest that the proposed approach could eventually lead to benefits in both, the fields of digital atlas cartography and digital education games.

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