3D GAMING AND CARTOGRAPHY - DESIGN CONSIDERATIONS FOR GAME-BASED GENERATION OF VIRTUAL TERRAIN ENVIRONMENTS

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Abstract

The potential of 3D gaming technology for 3D cartography has become more and more evident in the last years. This is due among other aspects to technological advances of the gaming industry. Due to this reason the authors present an approach aiming to demonstrate the possibility to obtain immersive geographic virtual environments cost effectively. To this aim freely available geographic datasets are used and a re-utilizable process is designed. In the preliminary study presented in this paper the generation of a virtual environment based on texture and elevation geographic datasets is evaluated. After fixing some restrictions and limitations both to the technology to be adopted and the datasets to be used, the selected input datasets are processed by two different, particularly for this experiment designed tools. The output delivered by the software is used as input for the terrain rendering engine. The same approach is adopted for two different datasets: one covering Central and Western Europe at lower and one covering a smaller region at higher resolution. By testing the approach on two different datasets it is aimed to demonstrate the re-usability (and therefore the cost-effectiveness) of the proposed method.

Through this first evaluation it is expected to gain important knowledge in the field of 3D gaming technology for 3D cartography and to collect valuable indications. This will allow a precise definition of future steps and concrete issues toward the realisation of an immersive 3D experience in a virtual environment. Possible concrete benefits can be imagined in several application fields such as in digital educational games or 3D digital thematic atlases.

Introduction

The potential of 3D gaming technology for 3D cartography has become more and more evident in the last years. This is due among other aspects to technological advances of the gaming industry. The utilization of 3D game engines is recognised as being a possibility to improve the quality of Geospatial Virtual Environments (GeoVEs). Research work in this direction is presented in several scientific publications (Germanchis and Cartwright, 2003; Germanchis et al., 2007; Herrlich, 2007; Friese et al., 2008). These studies underline the potential of computer games technology in relationship with cartographic visualization issues. The cited works show successful examples of scenes reconstructed in 3D based on existing geographic data. In all the presented examples the reconstructed area is up to some squared kilometres and can be observed in first person at close distance.

With the purpose of investigating these promising possibilities the Institute of Cartography of ETH Zurich joined the consortium of the EU founded research project '80Days – Around an inspiring virtual learning world in eighty days' (80Days; http://www.eightydays.eu/). In particular the goal of ETH Zurich in the consortium is to demonstrate the possibility to produce cost effectively 3D environments to be used in a Digital Educational Game (DEG). Due to the project's research goal and to the necessity to meet the requirements of all the involved partners restrictions both in terms of technology and utilizable data have to be considered. By dealing with these restrictions it is aimed to investigate the possible problems of using 3D gaming technology for 3D cartography in a different way than it would be possible by attentively selecting the technology and the data better suited for a specific experiment.

Cost effectiveness is considered in several aspects of the design process: freely available, not copyright protected data are used, manual editing is possibly avoided and an approach focusing on automation and on re-usability is designed. Considering these crucial aspects the presented study should result in the description of a general approach allowing the generation of GeoVEs in a semi automatic way with less restrictions on the geographic data to be used as input. Thereupon it would be possible to use the approach for the generation of 3D model of large terrains both representing photorealistic or thematic content. Examples of application fields could be 3D thematic atlases, DEGs or flight simulations.

Methodology

In order to carry on the experiment with reasonable amount of resources, the working framework is defined by fixing certain restrictions. For the generation of the 3D GeoVE only the utilization of digital elevation datasets and true colour satellite pictures is envisaged. Other geographic datasets both in raster and vector form are not considered. Due to the general requirements of 80days, the region of interest is defined as corresponding to Central and Western Europe. This restriction has an influence on the

geodata selection process. In addition to that, in order to demonstrate the possibility to cost-effectively realise DEGs, the 80Days consortium decided to use only freely available geographic data not concerned by intellectual property related issues. The main implication of this restriction concerns the spatial resolution of the available data. For the test described in this paper the concrete consequence is the utilization of datasets with a resolution of 30 respectively 3 arc-seconds, corresponding to the NASA Shuttle Radar Topography Mission (SRTM) elevation data available for the region of interest. True colour satellite pictures are resampled in order to match the characteristics of the elevation data.

Additional restrictions dictated by the 80Days consortium concern also the utilized technology. After considering various aspects and criteria, the consortium decided to adopt the Nebula 2 real-time rendering engine with the Mangalore game framework developed by Radon Labs (2009). This combination of rendering engine and game framework was mainly selected based upon experience and earlier projects of several of the consortium partners. Due to the nature of the project the game has to be able to run on ordinary PC's and not on state of the art gaming PC's. The fact that Nebula 2 does not support/require the latest generation of graphics cards played an important role in opting for this engine. The drawbacks of this choice consist in restrictions on the terrain engine work and in particular in the missing support of the latest generation of shaders on the graphic card.

Due to performance related issues (real time rendering at more than 30 frames pro second) as well as to storage related concerns, it is not possible to use the geographic datasets directly. One solution would be a conversion of the data by the game engine. However this happens not to be possible due to the aforementioned reasons. In order to solve the problem it is decided to develop external tools converting the data into a format more suitable for the engine. The data prepared by the specifically designed tools are used by the game engine for the generation of the terrain. In the presented preliminary approach, two different kinds of data are used. The texture provided by the satellite image is projected on top of the terrain generated using the information of the SRTM height map. The texture is split into 16 images each of 1024 by 1024 pixels in order to stay compatible with older generations of graphics cards. In our first test done with the low resolution datasets this corresponds to a spatial coverage of totally 4096 by 4096 km. Height data is stored at a resolution of about 1 km between each point. Each height value is stored using two bytes. The 3D mesh created from the height data is split up into smaller chunks of each 128 by 128 polygons. These are stored with different level of detail (data drawn in the distance is drawn with less detail). All the vertexes are projected in a spherical form, to give the impression of a round earth. It was decided to exaggerate the terrain heights to make the landscape more interesting to fly over. The level of detail approach and the spherical projection are illustrated in Figure 1.

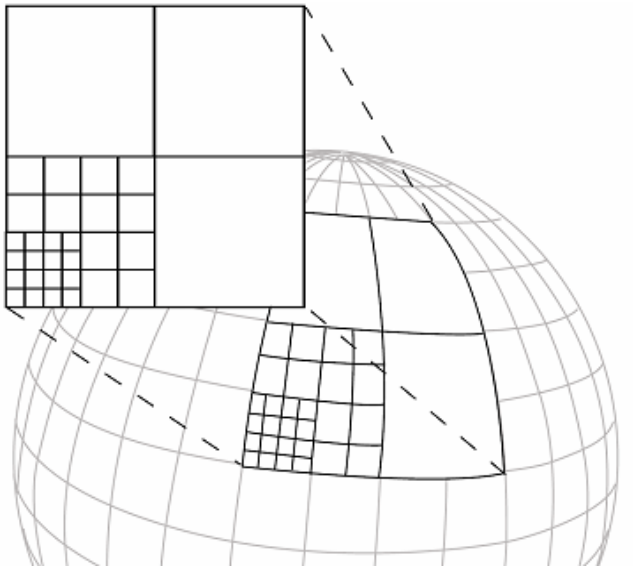

Figure 1: Sketch of level of detail and spherical form projection.

The same approach is replicated using both a texture and a height dataset at better resolution. The goal of this second step is to test the re-usability of the proposed approach and to evaluate the amount of work necessary in order to obtain the same result over different geographic areas. Both terrain and texture datasets for the region of Vienna are submitted to the processing chain still using 4096 by 4096 units. This results in a total spatial coverage of about 90 by 90 km.

Results

Applying the described approach to the selected datasets provided the results presented in Figure 2 and Figure 3. The differences in the two Figures in terms of graphical user interface are due to the utilization of the low resolution example as part of the first 80Days demonstrator. The example for the region of Vienna at better resolution has yet been only developed for internal research purposes. Figure 2 shows that the obtained results allow the user to freely fly over large parts of western and central Europe on a digital terrain similarly to a flight simulation. The choice of exaggerating the terrain for the visualization appears to provide a more interesting landscape to be flown over. Testing the obtained results with children shows good results in the possibility to recognise the flown areas. At the flying height defined by the purposes of 80Days, the chosen spatial resolution of about 1 km allows a good result in terms of visual effects. By navigating the terrain the result is even better than what is shown in Figure 2 due to the added movement aspect. It is also interesting to observe the nice effect of the simulated Earth's curvature. Due to the gameplay of 80Days, it was necessary to symbolize certain selected European cities on the terrain. In this preliminary study this is done using 3D light cones placed at the cities' position.

Figure 2: 3D terrain model generated with the lower resolution datasets. The obtained result has been used in the first demonstrator of the 80Days project.

Figure 3 shows the result obtained by adopting the same approach using different data. In this second test data at higher resolution are used with the purpose of modelling a different, smaller geographic area with a better level of detail and therefore allowing a lower flying over the terrain with reasonable visual quality of the virtual environment. The resulting terrain shows that the re-utilization of the same approach on different data is feasible. The second test required a very limited amount of works in term of code writing. An important part of the necessary resources was spent in the optimization of the code toward a more generalized approach. It is therefore expectable, that a third test would require even less work than the one presented here. This second test shows that datasets at higher resolution can also be used under the premise, that dimensions of the modelled area are adapted to the available storage space.

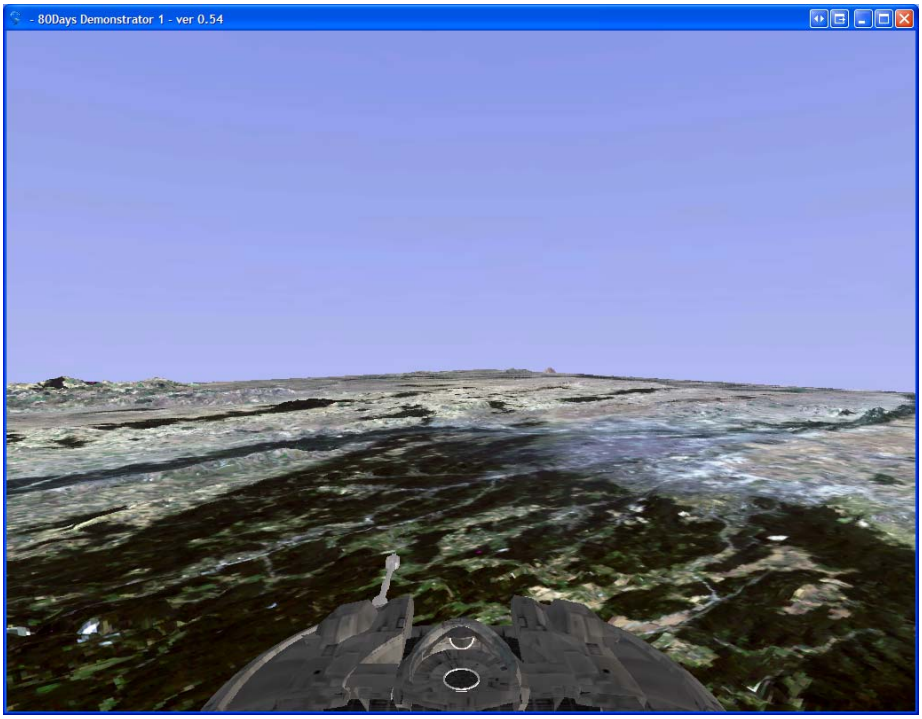

Figure 3: 3D terrain model generated with the higher resolution datasets for the region around Vienna.

Considerations and next steps

Figure 2 and Figure 3 shows the feasibility of the proposed approach. As presented in the previous section, the result is satisfactory and satisfies several of the aimed goals. Game technology can be used for the realization of 3D virtual environments requiring fewer specifications to the geographic datasets to be utilized. Due to this reason it has been possible to carry out the presented study using freely available geographic datasets not affected by restrictive copyright regulations. By showing additionally to this aspect the possibility to easily re-use the same approach on different datasets it has been possible to display the potential of obtaining sufficient results cost effectively. Nevertheless several aspects of the presented approach can be discussed and improved.
The choice of Nebula and Mangalore due to overall considerations of the 80Days project partly resulted in an engine that didn't fulfil all our wishes. Anyhow the result represents a good starting point and can be very useful for the 80 Days project. It was also decided to implement a terrain engine that would work with all data in memory; therefore no dynamical loading or generation of data takes place at the moment. The reason was mainly to have a terrain rendering in place for the project within the given time frame. This also meant that we are actually not supporting multiple resolutions (Also not a requirement of the 80 Days project at this stage). For future versions of the engine it is aimed to support multiple resolutions of both terrain heights and textures. Two possibilities are to let terrain rendering engine handle multiple resolutions (not all

areas will have same resolution) or to extend the developed tools in order to accomplish this task. Handling the multiple resolutions issue through the rendering engine will mean that the 3D mesh will have to be generated from different resolutions at run time. By handling the same issue using the external tools, a single dataset would be exported. A decision about this point is planned at a later stage. Anyhow proceeding toward handling larger areas at multiple resolutions will lead to the necessity to work dynamically: data will need to be loaded and 3D meshes to be generated in real time while the user navigates the virtual reality (out of core rendering).

From a more conceptual point of view some more general questions may be raised. One issue concerns the current limitation to geographic datasets in raster form. The actual projection of a 2D image on the terrain appears to be inefficient both in terms of achievable spatial resolution (when considering freely available geographic datasets) and efficient handling of storage space. An approach based on a segmentation of the land cover information of the underlying terrain using vector datasets as proposed by Herrlich (2008) looks promising. This kind of approach would result in the definition of a set of rules to be applied by the rendering engine depending on the (eventually simplified) information contained in the segmentation vector file. One great advantage of this method could be the possibility to adapt the set of rule according to the user's necessities: libraries of (3D) symbolizations could be prepared ranging from a strongly photorealistic to a more abstract, strongly symbolized view. This can happen at a very basic level only in form of textures and at a more elaborated stage in form of 3D objects/symbols. Before more attentive research work in this direction can be done, the implementation of pre-existing 3D models in the virtual reality should be tackled. This includes not only the handling of 3D objects by the game engine, but also a series of issues related to the representation of linear features in a 3D terrain and the related artefacts (roads with non-horizontal cross direction profile, upwards flowing rivers, etc.).

Conclusions

The proposed approach shows good results in the utilization of computer games technology for the realization of 3D virtual environments on the basis of freely available, not copyright protected geographic datasets. At the same time several concrete issues can be highlighted by the presented preliminary study both in the field of the game-engine related technical aspects as well as in the field of 3D visualization and symbolization. The test presented in this paper indicates in particular the possibility to obtain 3D virtual environments in a cost effective way by focusing on designing a general approach and using geographic datasets without specific constraints as input.
Further research efforts are imaginable in dynamically handling multiple resolution datasets, defining visualisation rules based on thematic information as well as in 3D symbolization and generalization. Thanks to these future efforts the goal of providing an immersive experience in a 3D virtual environment could be achieved. This could

possibly result in benefits in several concrete application fields such as DEGs (similarly to 80Days) or 3D digital thematic atlases.

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