

3D REAL TIME VISUALIZATION FOR SUPPORT OF ARCHAEOLOGICAL ANALYSIS

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ABSTRACT:

Within the longterm research project Nasca/Palpa, which has been conducted at the group of photogrammetry and remote sensing of ETH Zurich since 1997, an archaeological GIS-database describing the famous ground drawings of the *Palpa* region and a wide variety of terrain data and orthoimages were produced at different levels in terms of accuracy and spatial resolution. In order to visualize these data in a real time 3D environment, the Skyline Terra Builder and Explorer Pro software packages were chosen due to their capabilities of integration of different layers with different resolutions. A second important feature of the used software is the option to enhance the spatial content by further elements, such as still and dynamic 2D and 3D objects, Quicktime™-panoramas and -movies, labels and flight paths, by means of an integrated scene description language. In our case, these options were used to add results from GIS-based analyses applied to the geoglyphs in Palpa, e.g. visibility studies, and to verify them inside the 3D environment.

1 INTRODUCTION

Since 1997, the Institute of Geodesy and Photogrammetry (IGP) at ETH Zurich is actively involved in the transdisciplinary research project Nasca/Palpa in cooperation with the Commission for Archaeology of Non-European Cultures Bonn of the German Archaeological Institute (DAI-KAAK). During this period, several photogrammetric and GIS-related sub-projects were accomplished at our institute in order to support archaeological research by means of generation of photogrammetric products such as DTMs, DSMs, orthoimages and 3D topographic vector data. A second field of research was the development of methods and software for GIS-based analyses adapted to investigations on the function and meaning of the famous geoglyphs, the so-called "Nasca Lines". Over the years, a comprehensive collection of different data sets was generated and so far was only visualized in standalone modes (Lambers and Sauerbier, 2003, Lambers et al., 2007, Sauerbier, 2008) or in partly integrated visualizations (Sauerbier et al., 2006) using point-based rendering. Furthermore, results of analyses were not included in 3D visualizations aside from still views generated in GIS-software (Lambers, 2006, p. 113-115).

The goal of the work presented here does not focus on the visualization performance of a certain software, but proposes concepts how to apply 3D visualization as a tool for archaeological work beyond mere presentation purposes. A performance evaluation of the here applied software in comparison with a 3D graphics engine from the game development domain conducted recently by our group will be published elsewhere.

1.1 Area of investigation

The area of investigation is located in Peru, approximately 400 km south of *Lima*. The spatial extent of the produced data covers an area of 13.350 km² from the modern city of *Ica* in the west to the Andes east of the city of *Nasca* and from the south coast around *Monte Grande* to the Andes village *Corontayo* in the north. The region contains a rich cultural heritage in terms of settlement and cemetery sites (Reindel et al., 2001, Sossna, 2007), monuments (Silverman, 1993), geoglyphs (Kosok and Reiche, 1949, Aveni, 1990, Reindel, 2007, Lambers, 2006) and pet-

roglyph sites (Pavelka, 2007, Fux et al., 2008a, Fux et al., 2008b, Sauerbier et al., 2008) which are since the 1920s subject of archaeological research.

Figure 1 illustrates the area of investigation.

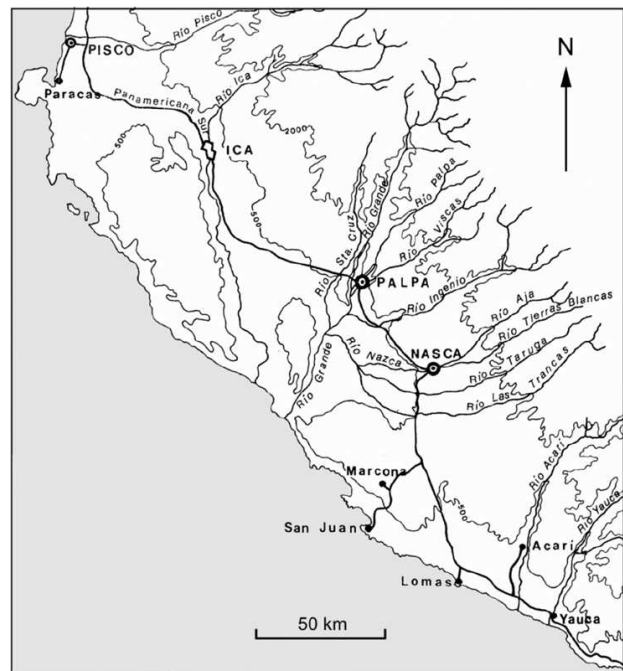


Figure 1: The area of investigation in south Peru

1.2 Available data

The terrain, orthoimage and vector data available within our project and the according procedures for their generation were already described in detail elsewhere (Lambers, 2006, Lambers et al., 2007, Sauerbier, 2008, Lambers and Sauerbier, 2006), therefore tables 1 and 2 give a brief overview of the image and terrain data

utilized for the work presented here. In addition to the raster data, the mapped geoglyphs were available as a 3D vector data set in polygonal representation. All spatial data refer to the UTM Zone 18 S with the WGS-84 ellipsoid as horizontal and vertical datum. The whole data set features approximately 50 GB, with 48 GB of image data and 2 GB of terrain data in uncompressed formats.

Table 1: DTM data generated within the Nasca/Palpa project

Data set	Grid	Method of Generation
DSM Pinchango Alto	10 cm	UAV images
DSM Pinchango Alto	5 cm	Terrestrial laser scanning
DTM Palpa	2 m	Aerial images 1:7'000
DTM Pampa de Nasca	5 m	Aerial images 1:10'000
DSM Nasca Region	30 m	ASTER satellite imagery

Table 2: Orthoimage data generated within the Nasca/Palpa project

Data set	Footprint
Orthoimage Pinchango Alto	3 cm
Orthoimage Palpa	28 cm
Orthoimage Pampa de Nasca	15 cm
Orthoimage Nasca Region	30 m

2 3D VISUALIZATION USING SKYLINE

The Skyline Terra Builder (version 1) and Explorer Pro (version 3) software package (Skylinesoft Inc.) is a real time visualization tool specialized on 2,5D terrain data with texture, though it offers the option to import also real 3D objects such as buildings and others from CAD data formats (DXF, ESRI shapefiles).

2.1 Integration of multiresolution data

The procedure of integrating layers of different resolution into the 3D model was accomplished using the Terra Builder. In a first step, all data had to be imported to the proprietary data format, then for each layer a bounding polygon could be defined in order to determine the part that should be included in the final 3D model. For multiresolution layers, a small overlap between neighboring layers is recommended to take advantage of the feathering function which provides for smooth transition between layers of different resolution, be it geometric data or texture. Thus, a visually highly qualitative visualization of the multiresolution data could be obtained as figure 2 illustrates, though no information was published by the software developers on the methods implemented to handle the overlapping regions, or to be more precise it is not clear how Skyline processes a) the DTM and b) the orthoimage data in these regions.

Figure 2 shows a subset of the multiresolution 3D model, in particular one can distinguish the outer part, where the underlying DTM Palpa (cp. 1) features a grid size of 2 m and the B/W orthoimage Palpa (cp. 2) has a footprint of 0.28 m, and the inner part where the DSM Pinchango Alto (cp. 1) generated from UAV images with 0.1 m grid size and the orthoimage Pinchango Alto (cp. 2) with 0.03 m footprint are displayed. 1

2.2 The integrated scene description language

The Terra Explorer allows to store the files, which define the behaviour of the 3D model during the navigation and the further contents, in binary (.FLY) or ASCII (.TEH) formats. While the first can be edited in a user-friendly way inside the Terra Explorer, the second due to its nature being an ASCII file can be edited arbitrarily with the advantage that some of the features can be generated repeatedly by scripting. The following features of the resulting visualization environment can be controlled via the TEH file:

- The 3D visualization container: maximum viewing distance, fog distance and color, start position and attitude of the virtual camera.
- The flight model: min./max. speed in all coordinate directions and in rotation, acceleration and deceleration for speed and rotations, min./max. altitude, min./max. zoom level.
- Containers for info tree, web page, logos, and 3D and geo-referenced map display.
- Locations: allows to store points of interest as quickly accessible viewpoints.
- Routes: flight paths, which can be recorded as video files.
- 2D primitives: a set of predefined primitives 3.
- 3D primitives: a set of predefined 3D primitives.
- Image placement inside the 3D model (JPG, BMP, GIF).
- Labels allows to place textual labels, e.g. toponyms, inside the 3D model.
- Dynamic objects: this function can be used to place 3D objects in the model by giving them a defined route that they move along. These objects are allowed to either move on the terrain or to fly and can be linked to each other.
- Layers allows to import and display (or switch off) DXF layers.
- Messages allows to display text messages in a separate container.

Inside the scene description file, a flag denotes which type of object is described in the next section, then in a defined order typical for each object the parameters which control its display are stored.

For our purpose - the enhancement of the 3D model with archaeological information and results - various of these functions can be employed (compare 2.3). 1

2.3 Integration of analysis results

One example are remains of wooden posts found on several trapezoidal geoglyphs near *Palpa* which featured a height of approximately 4-5 m over ground and were used as target features in a visibility study (Lambers, 2006). Figure 4 shows the viewshed for a post found on the *Cresta de Sacramento* in the west of *Palpa*.

Using the 3D primitives, in this case a cylinder, the known posts could be integrated into our textured 3D model with different heights such that a visual verification of the results of the viewshed calculations was enabled. Additionally, the according viewshed rasters were vectorized and integrated as well as a 2D polygon layer which overlays the terrain transparently.

A second type of result from GIS-based analyses which was integrated into the 3D model were lines of sight determined from investigations on geoglyph orientations (Lambers and Sauerbier, 2008), in particular with respect to mountain peaks. In this case, a visual verification of the results using the 3D model is of great importance due to the fact that the orientation computations imply uncertainties caused by geoglyph mapping accuracy, DTM accuracy and uncertainty of the mountain peak definition and its representation by the DTM. Visual verification therefore serves as an additional source of information in order to classify geoglyphs



Figure 2: 3D view towards the pre-Inka settlement site of Pinchango Alto. The central settlement area features a DSM grid size of 10 cm and an orthoimage footprint of 3 cm while the surrounding area is covered by a DTM which provides a grid size of 2 m and 28 cm orthoimage footprint.

```
[2D_PRIMITIVES]
0 = 6 2 0 255 0 255 0 0 1 5 479837.403125 8395492.100000 0.000000 548.059540 (Ang) 0.000000\
(SN) 101 (Msg) -1 (TlTp) <{}<> (InTr2) -1 0 1 (Dscrip) <{}>New Regular<{}> (Rds) 500.000000\
(AO) 0 0 25.000000 25.000000 25.000000
1 = 6 2 0 255 0 255 0 0 5 480476.167401 8395721.310460 0.000000 190.250630 (Ang) 0.000000\
(SN) 102 (Msg) -1 (TlTp) <{}<> (InTr2) -1 1 0 (Dscrip) <{}>New Regular2<{}> (Rds) 500.000000\
(AO) 0 0 25.000000 25.000000 25.000000
```

Figure 3: Example for Terra Explorer SDL code



Figure 4: Result of a single viewshed calculation for a wooden post situated on a geoglyph, source of the figure: (Lambers, 2006). The red dot marks the position of the post which was visible from the areas marked in green.

with respect to orientation towards mountain peaks.

By integration of those lines of sight which were assumed to be directed towards a peak and positioning the virtual camera on the according point of observation the line of sight can be visually checked and interpreted. Figure 5 shows the calculated lines of

sight near *Palpa* which were identified to point in direction towards a mountain peak and were imported to the 3D model for visual inspection (figure 6). 1

3 CONCLUSIONS

The presented enhancement of textured 3D models by archaeological features directs the usage of virtual reality apart from mere presentation towards being a tool for analytical work. Especially visibility studies can be easily conducted without requiring expert knowledge in GIS software but exploiting the functionality present 3D terrain visualization software offers in a much more user-friendly though interactive mode.

The here applied Skyline software serves as a suitable example, however similar software exists, both commercially and freely available or in the open source domain, for the purpose of enhancing reality-based textured 3D models by analysis results. Google Earth™, Microsoft Virtual Earth™ or NASA WorldWind™ are other examples of real time 3D viewers which allow to a certain extent the import of data by the users. Expert knowledge is required mostly only for the production of the 3D model in terms of data acquisition and processing while the enhancement of the virtual scene with archaeological features can usually be handled by an untrained person. A feature that is still missing in these 3D visualization software packages is the capability to access external databases online, e.g. by clicking on spatial objects in the viewer and formulating a query on these objects. Such functionality so far mostly was implemented in research prototypes (Forte et al., 2001, Henze et al., 2005).

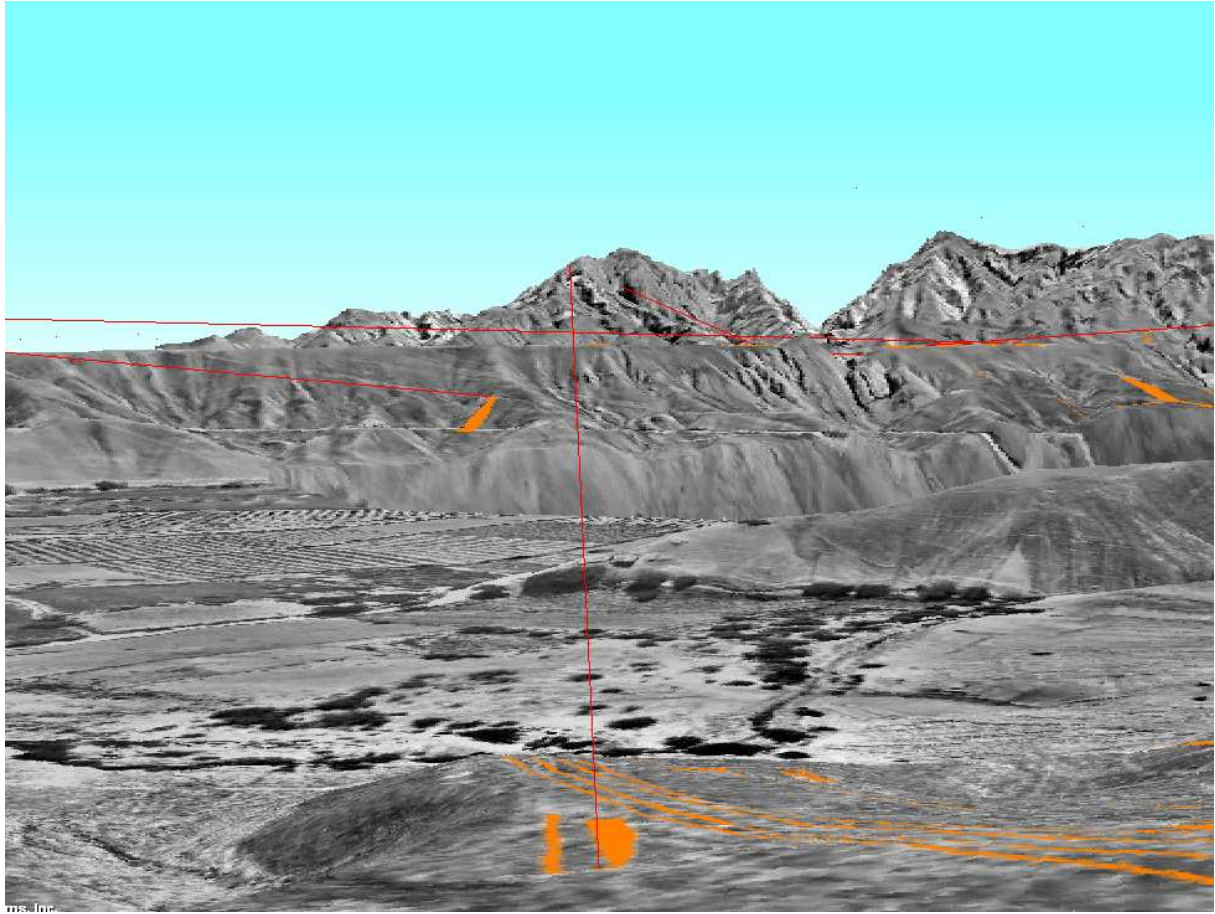


Figure 6: Example for a line of sight pointing towards the *Pinchango* peak visualized in Skyline Terra Explorer. Red lines mark lines of sight, orange polygons represent the geoglyphs.

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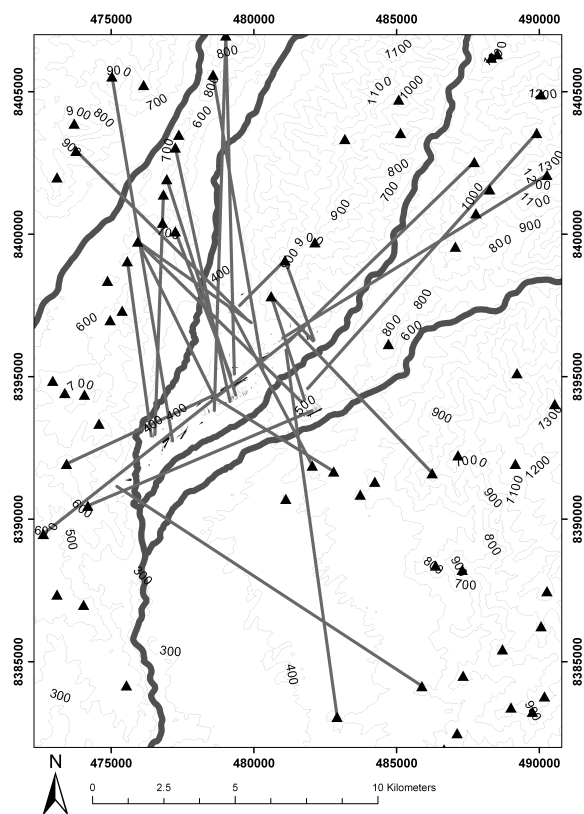


Figure 5: Lines of sight from geoglyphs towards mountain peaks.

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