The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Commission V, Part B2, Beijing 2008, pp. 241-246.

INTEGRATION OF 3D DATA, TEXTURE AND ARCHAEOLOGICAL INFORMATION IN A DATABASE MANAGEMENT SYSTEM FOR PETROGLYPH DOCUMENTATION AND INTERPRETATION

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Commission V, WG V/2

KEY WORDS: Archaeology, Databases, Digitization, GIS, Interpretation, Modelling, Multiresolution

ABSTRACT:

Within our long term interdisciplinary project Nasca/Palpa modern 3D data acquisition techniques were applied for different purposes successfully in the past, particularly for mapping of large and medium scale decorations found in the landscape such as the famous geoglyphs in the Palpa and Nasca regions as well as the petroglyphs of Chichictara. Archaeologists involved in research on the Nasca culture (200 B.C. – 650 AD) and its predecessors (Paracas, 800 – 200 B.C.) are interested in the cultural and spatial development of these cultures, therefore, a common database of the aforementioned decorations is planned in order to enable investigations on relations and similarities of the motives. In this paper, we mainly treat the development of a spatial and semantic database for the petroglyphs, which were recorded in 3D by means of terrestrial laser scanning and close range photogrammetry during a field campaign in 2006.

1.INTRODUCTION

Interdisciplinary research deals with the settlement history in the Nasca and Palpa region about 400 km south east of Lima in Peru since 1996. The long term archaeological project Nasca/Palpa is being coordinated by the German Archaeological Institute, Commission for Archaeology of Non-European Cultures (DAI, KAAK, Bonn), while the chair of photogrammetry and remote sensing at the ETH Zurich was responsible for the acquisition of spatial data and the development of a GIS database in order to enable the archaeological interpretation especially of the geoglyphs in the Palpa region which led to new insights into the geoglyph functions (Lambers, 2006, Lambers and Sauerbier, 2008) in combination with the analysis of archaeological evidence. It has to be noted here, that without the support of the Swiss-Liechtenstein Foundation for Archaeological Research Abroad (SLSA) the extensive field work would not have been possible.

Figure 1: View from the Río Palpa valley towards Chichictara. The ellipses mark the two main petroglyph areas.

The GIS database describing the geoglyphs which was developed within this project provides a valuable data source for the investigation of semantic and spatial relations between petroglyphs and geoglyphs.

2.ARCHAEOLOGICAL SITE CHICHICTARA

The Chichictara archaeological site documented within this project is located in a xeric side valley of the Río Palpa valley, about 11 km north east of Palpa, and consists of 4 sectors with petroglyphs. The geographical coordinates of the site documented in 2006 (Sector 2), the sector with the largest agglomeration of petroglyphs in Chichictara, are approximately 14°27'50.9'' S in latitude and 75°07'59.6'' W in longitude. The recorded petroglyph site covers an area of ca. 200 x 300 m^2 and contains 67 petroglyph objects picked into the rock surface during the Paracas period (800 – 200 B.C.). Figure 1 illustrates the landscape characteristics in the Chichictara valley.

2.1 Project Goals

Within the Chichictara project we aim for the development of a spatial and semantic database suited for visualization and analysis tasks to support archaeological interpretation of the function and meaning of the petroglyphs in their natural context.

The acquired data and the derived products represent a challenge in terms of their integration into a database management system due to several reasons:

- In case of the full resolution 3D point cloud from terrestrial laser scanning the size of the data set is relatively large (27 millions of points). The same applies to the ASTER-DSM.
- The 3D rock models require the texture to be stored in an appropriate way, including texture coordinates and the according 3D faces.
- The digitized 3D vectors representing the petroglyph drawings had to be stored as discrete objects, nevertheless including their link to the according rock model.
- A connection between the 3D geometry and the semantic part of the data model had to be established and a solution for efficient query, preferably inside the 3D visualization, has to be implemented.
- A connection to the existing GIS database of the Palpa geoglyphs should be possible.

Further requirements are preferably simple access to the database via forms in a web browser for data input and query of the semantic data such that non-database experts are enabled to work efficiently with the system. 3D visualization of the textured rock models combined with the display of attribute data, a solution for real time visualization of the integrated rock models and the laser DTM are further requirements for archaeological work with the available data. The opportunity to display results from database queries inside the 3D visualization, e.g. in form of a hyperlink that displays the result of a pre-defined query, would also be desirable.

Our approach to store the 3D data as well as the scene control parameters inside a relational Database Management System (DBMS) allows the data being managed independently from a file system and from 3D data formats. By means of conversion tools which will be implemented in procedural languages provided by modern DBMS visualizations in the 3D data formats relevant for our project work, such as VRML and COLLADA, can be generated.

2.2 3D Data Acquisition

The 3D data acquisition methods applied for high resolution terrain modelling from terrestrial laser scanning as well as for 3D modelling of the petroglyph rocks and petroglyph digitisation (Figure 2) were already described at earlier occasions (Lindstaedt et al. 2007, Sauerbier et al. 2007). It has to be stated here, that textured 3D models of the petroglyph rocks as well as 3D vector data representing the digitisations of the decorations are at our disposal in VRML format.

While terrain modelling could be finished in 2007, the photogrammetric modelling of the decorated rocks and petroglyph digitisation currently are still in process. At the present state, the required images from all image blocks are oriented in arbitrary coordinate systems and the production of textured 3D models is accomplished for 25 blocks (Figure 3).

The laser scan DTM was transformed from the local coordinate system to UTM Zone 18 S coordinates by means of common points. These points were signalized with spherical targets in order to identify them clearly in the laser scans and additionally measured in the UTM system by means of Trimble GeoExplorer XT instruments. Figure 2 shows a shaded relief of a resampled version of the laser scan DTM with a mesh size of 50 cm, overlaid with the positions of petroglyphs in the Chichictara valley in UTM coordinates.

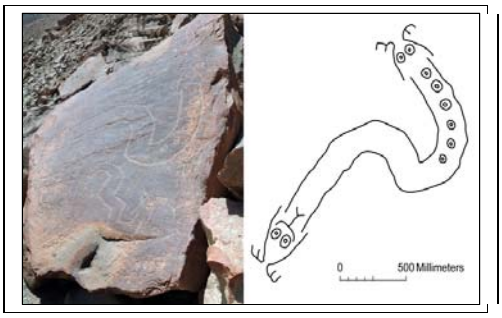

Figure 2: Example of a petroglyph rock and the digitised petroglyph. Note that the digitization was performed in 3D.

Figure 3: Example of a textured model of a petroglyph rock

The textured 3D models of the petroglyph rocks currently are being transformed to the UTM system by means of the software Geomagic Studio. Using an iterative closest point algorithm, the 3D rock models are being registered with respect to the full resolution laser scan point cloud. For this purpose, 3-4 common points have to be measured manually as initial approximations, and then the registration transforms the floating model. In order to preserve the correct texture for each face, we perform the transformation using a non-textured version of the VRML file and after transformation replace the old coordinates of the face vertices in the textured VRML file. Due to the fact that the texture maps are connected to the faces via the face set-ID, a coordinate transformation does not affect the correctness of the texture assignment.

Additionally, from a set of 6 ASTER satellite image scenes, a DSM and an orthomosaic were generated using the Leica Photogrammetry Suite (LPS) photogrammetric software. These medium resolution data cover an area of about 13350 square kilometres, from the Pacific coast to the area around the Andean village of Laramate and from Icá in the west to ca. 60 km east of Nasca.

Figure 4 illustrates the overall workflow of data acquisition, modelling and integration for this project.

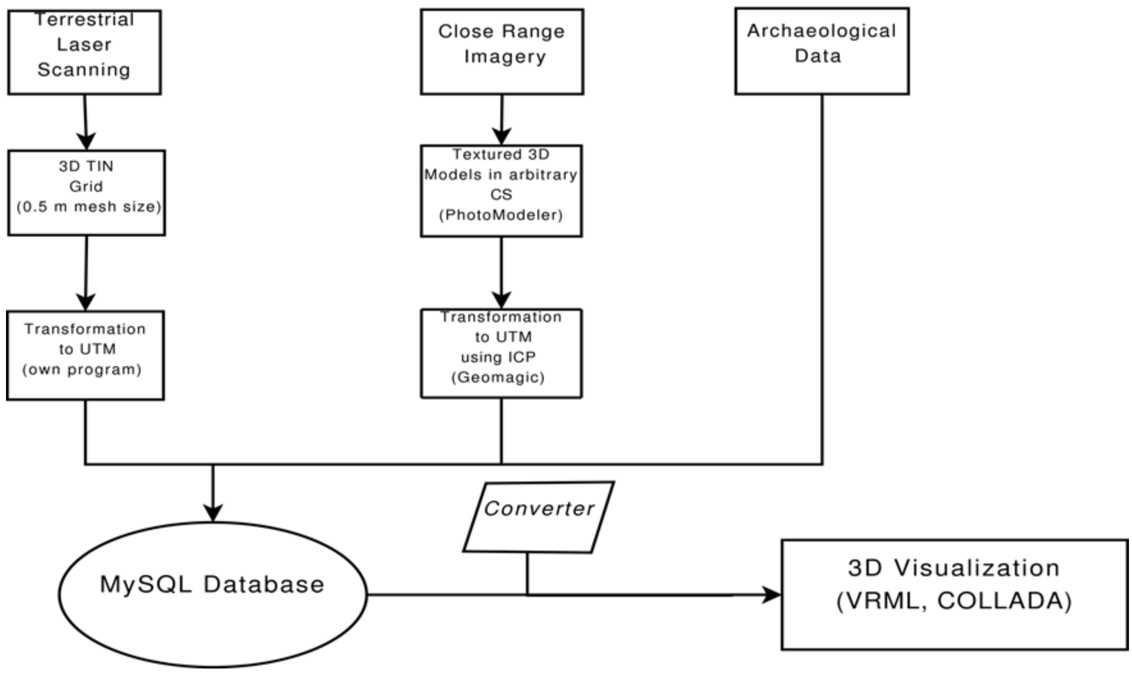

Figure 4: Workflow for data integration into the MySQL Database Management System

3.DEVELOPMENT OF THE DATABASE

3.1 Conceptual Data Model

The conceptual data model for both, the semantic and the geometric part, was designed using the Unified Modelling Language (UML). In order to be able to directly export the graphical UML-model into the database software, the Open Source software Umbrello (www.uml.sourceforge.net) was deployed which supports SQL and XMI export. In spite of the available export functions of Umbrello, resulting SQL-DDL code has to be slightly adapted to the syntax of the deployed DBMS, in our case MySQL 5.

3.1.1 Semantic Data Model

For the semantic data on the petroglyph drawings, we geared to iconographic properties of petroglyphs which in turn determine their typology (Figure 5). The core here is the AR_Petroglyph object, which carries the essential attributes acquired during archaeological field work and specializes into subtypes based on the iconography. The core element is the class AR_PETROGLYPH which contains the basic information which is common for all petroglyphs. Furthermore, we created classes for the results of visibility analyses (visibility_map) which will later be specified more in detail, and AR_IMAGE which lists the images connected with each petroglyph. The lower part of figure 5 contains the typological specialisations according to the so far identified types of petroglyphs, namely descriptive petroglyphs (DESCRIPTIVE, subdivided into ANTHROPOMORPHIC and ZOOMORPHIC), vegetable, scenic and geometric petroglyphs. These types result from the content displayed by a petroglyph, the examples shown in figures 2 and 3 would be members of the ZOOMORPHIC class due to the fact that they show illustrations of animals.

The semantic part can still be subject to modifications in the future due to results from archaeological interpretation in terms of petroglyph typology.

3.1.2 Geometric Data Model

In case of the geometric data modelling, we mapped concepts available in different recent virtual reality modelling languages, mainly VRML/X3D and COLLADA, to the UML model (Figure 6). Similar approaches were proposed and successfully applied for a 3D building model by Žára and Černohorský in 2000. Nevertheless, we did not aim for a complete translation of all available concepts into the conceptual data model but exclusively for those concepts which were meaningful for our purposes. The result is a scene graph which represents a subclass of the aforementioned scene description languages in terms of its nodes.

In order to ensure the connection to the semantic part of the database, each geometric entity, e.g. a shape, was assigned the according petroglyph identifier (P_ID). The 3D geometry was stored in the point coordinate class and the face topology in a separate class.

Furthermore, different classes contain parameters which control the appearance of the scene and of the single objects inside (Table 1). The image files required for texture mapping will be stored in the file system. Nevertheless, via their URL or file paths they can be accessed for visualization.

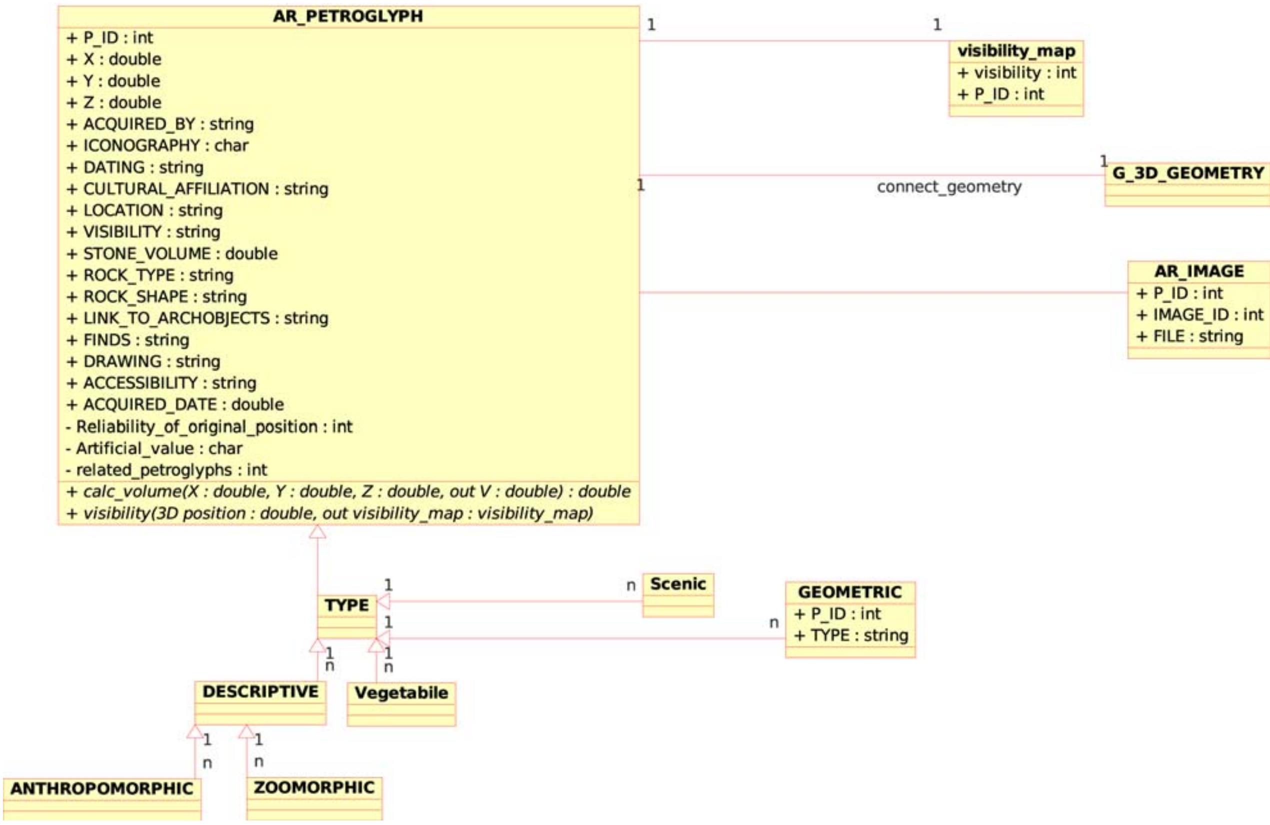

Figure 5: UML model of the semantic part of the implemented database featuring archaeological data describing the typology of petroglyphs

Class	Function
Background	Defines the colours, including colour transitions, and the angle for the virtual sky and ground.
Viewpoint	Allows storing defined viewpoints with the observer's position and attitude and a description.
Spot Light	Light radiated conformally from a point source. Parameters allow controlling ambientIntensity, attenuation, beam width, colour, direction, intensity, location, angle of the light cone, and the radius. Can be switched OFF/ON.
Directional Light	Parallel directed light, controlled via the parameters ambientIntensity, colour, intensity, and direction. Can be switched OFF/ON.
Point Light	Light radiated by a point source in all directions. Controlled by parameters ambientIntensity, attenuation, colour, intensity, location, and radius. Can be switched OFF/ON.

Table 1: Classes for control of the scene appearance

3.2Software Issues

The choice of software plays an important role especially in interdisciplinary projects where researchers from different disciplines access the same data. Therefore, user friendliness was one of the key factors for the decision, which software to deploy for the different steps of the data integration procedure as well as for the access to the data for visualization and query. While the 3D processing and modelling procedures had to be conducted by experts in these fields, we relied on available commercial software such as PhotoModeler for photogrammetric processing and Geomagic Studio for processing of the laser scan data and the transformation of the 3D rock models to the UTM Zone 18 S coordinate system. Additionally, tools were implemented to facilitate the handling of the different data sets.

As a database management system we selected MySQL for our purposes due to the fact that it is freely available and offers various tools for simple data definition (MySQL Administrator) and query (MySQL Navigator). MySQL is a relational database management system (RDBMS).

Using PHP as a scripting language, one can develop additional tools and forms for data access from webpages. In combination with the Apache server software, database access via the internet can additionally be provided. In contrast to commercial systems which are designed for large amounts of data and users, MySQL requires only few administrative tasks to be conducted by the user. Moreover, these tasks can easily be automated, e.g. backups. Connectivity and compatibility to the geoglyph database, implemented in Oracle 10g, is possible via the MySQL import functionality or via SQL except for marginal SQL syntax differences.

MySQL already was applied successfully as a RDBMS for spatial data in cultural heritage applications before (Henze et al. 2005, Heine et al. 2006, Žára and Černohorský 2000) and therefore can be regarded as a suitable and freely available tool for petroglyph data management as well.

4.CONCLUSIONS AND OUTLOOK

A data model and a workflow for 3D petroglyph data integration into a Open Source relational database management system were presented. The advantages of the presented system are the free availability of the deployed database software, the storage of geometric data independently from proprietary data formats according to a well documented schema and the comparably low effort for database maintenance. Furthermore, we have developed a database structure that fulfils the needs of archaeological interpretation of the petroglyphs and enables their comparison to other decorations from similar cultures. In future work, depending of available funding, we plan to develop methods which are generally valid for archaeological decoration analysis based on 3D models. These decorations may be situated on ceramics or even in the landscape, therefore a scale-independent approach will be set up. A planned integration of various databases into a Digital Library opens new perspectives of common data interpretation of decorations from different cultures, different geographic locations and different time periods. A second work planned for the future is to integrate data from further petroglyph sites in the vicinity of Chichictara in order to compare them iconographically but also to investigate cultural relations between the peruvian south coastal region and the Andean mountain region.

ACKNOWLEDGEMENT

The authors thank J. Peterhans, T. Graeger, K. Troxler and M. Schmid for their valuable contributions to photogrammetric processing. Special thanks go to the Swiss-Liechtenstein Foundation for Archaeological Research Abroad (SLSA), who funded the field campaign in 2006 and the subsequent data processing.

REFERENCES

Heine, K., Brasse, C., Wulf, U., 2006. WWW-based building information system for Domus Severiana Palace in Rome by Open Source software. In: Ioannides, M., Arnold, D., Niccolucci, F., Mania, K. (eds.), *Proceedings of the VAST 2006 conference*, Eurographics Association, pp. 75-82.

Henze, F., Lehmann, H., Fischer-Genz, B., 2005. Development of an internet-based information system for archaeological research and studies on urban history in Baalbek/Lebanon. In: Dequal, S. (ed.), *International Cooperation to save the world's Cultural Heritage,* Proceedings of the XXth CIPA Symposium, pp. 849-854.

Lambers, K., 2006. The geoglyphs of Palpa, Peru: Documentation, Analysis and Interpretation. LindenSoft.

Lambers, K., Sauerbier, M., 2008. A fresh view on the Nasca lines: Investigating geoglyph visibility in Palpa (Ica, Peru). In: *Digital Heritage: Exploring new frontiers in human heritage,* Proceedings of the 34th CAA conference, Fargo, USA, Archaeolingua, pp. 228-238.

Lindstaedt, M., Kersten, T., Sauerbier, M., Peterhans, J., Fux, P., 2007. Dokumentation der Petroglyphen von Chichictara durch terrestrisches Laserscanning und digitale Photogrammetrie. *Photogrammetrie – Laserscanning, Optische 3D Messtechnik, Beiträge der Oldenburger 3D Tage 2007, T. Luhmann, C. Müller (eds.),* Herbert Wichmann Verlag, pp. 328-337.

Sauerbier, M., Fux, P., Lindstaedt, M., Kersten, T., Peterhans, J., Belkaïd, M., 2007. Dokumentation und 3D Modellierung der Petroglyphen von Chichictara (Peru) mittels terrestrischem Laserscanning und Photogrammetrie. *Publikationen der Deutschen Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation e.V., Vol. 16,* E. Seyfert (ed.), pp. 425-433.

Žára, J., Černohorský, D., 2000. On Design of 3D and Multimedia Extension of Information System with VRML. In: *Proceedings 3rd Workshop on Virtual Reality*. Rio de Janeiro : Brazilian Computer Society - SBC, pp. 99-106.

REFERENCES FROM WEBSITES:

http://www.uml.sourceforge.net (last accessed 25.04.2008).

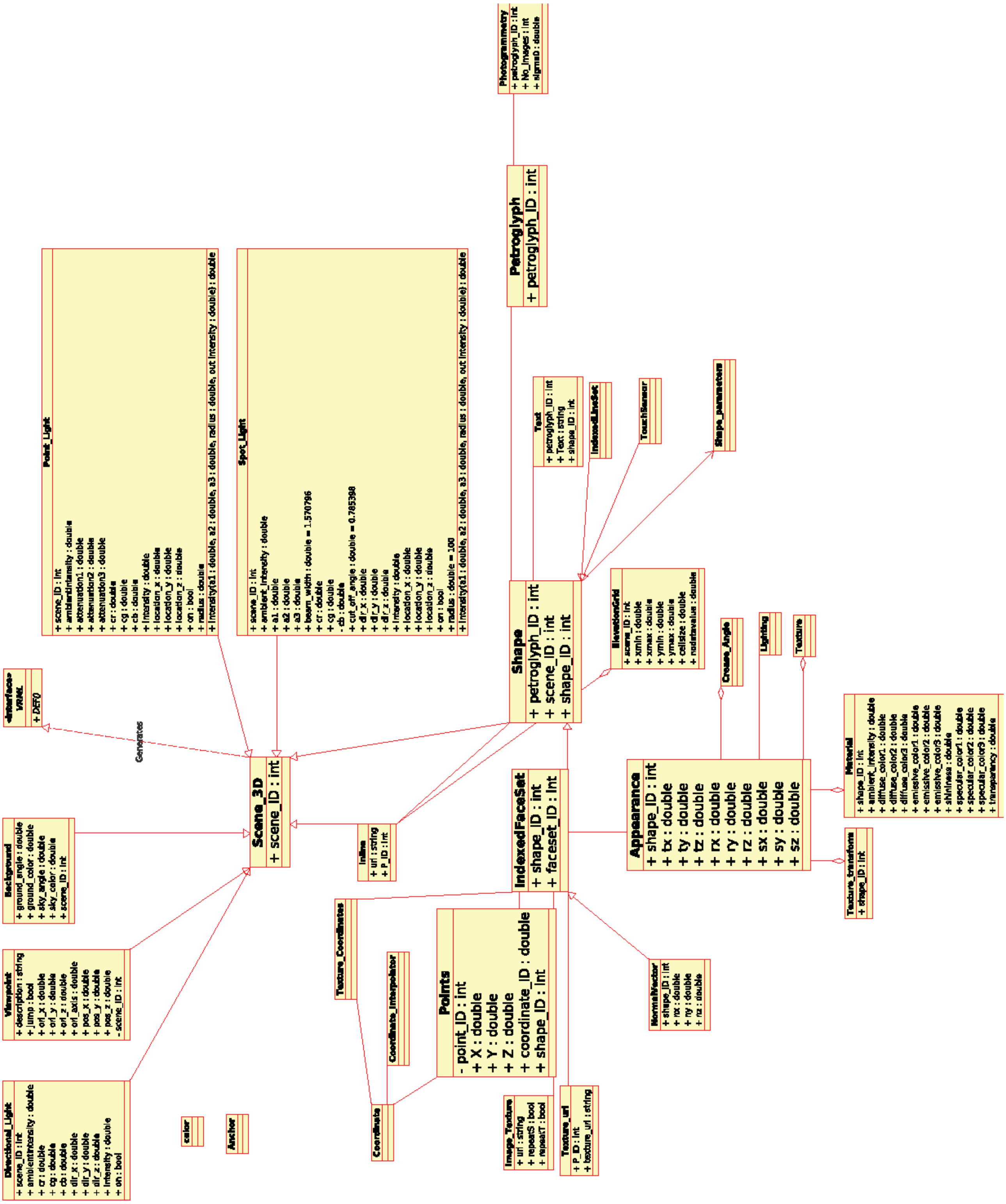

Figure 6: Geometric part of the conceptual data model