Geometric characterization and analysis of complex elements through the integration of different Geomatics Techniques. Application to caves

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Abstract

The importance given to geomatics within speleology, is that any study after the discovery of a cavity needs a plane on which to rely. Hence the survey is one of the first tasks that are performed. Traditionally, topography was aimed at the final drawing of a plant, a longitudinal profile and some sections. The integration of traditional geomatics tools such as GNSS and total stations with more recent ones such as 3D laser scanners, allows a fast and accurate registration process in order to obtain a comprehensive documentation that covers everything from floor plans, elevation, longitudinal and transverse sections, dimensional analysis and calculation of heights of galleries or caps and to virtual reality systems. This article describes the necessary tasks in both the capture and treatment of the data to generate highly accurate metric documentation and details of such complex and unique places such are caves and cavities.

Keywords: *Cartography, Caves, GNSS, photogrammetry, 3D laser scanner, 3D modelling algorithms*

1. Introduction

Having an accurate map base of a cavity in both 2D and 3D, is important when dumping the captured information, interrelate parameters and conduct effective management of it, although it may become essential when developing and testing predictive models based on knowledge.

In caves, every day more studies are conducted:

- Hydrochemical studies: Systematic studies of the physical and chemical characteristics of the water, is one of the methods for monitoring the evolution of the karst. It contains information as pH, water temperature, conductivity, total dissolved solids, dissolved CO2 and dissolved O2.

- Water Microbiology.

- Climate Study: The presence of people inside the cavities can generate different types of thermal, chemical and biological pollution. The number of people who remain some time daily in the cave is a major source of heat generation and CO_2 supply to the confined atmosphere. Therefore, the definition of a threshold equilibrium must be a common practice in environmental management of any tourist cavity, allowing to establish an optimal regime of visits. This is fundamental for the karst heritage conservation.

- Fauna Studies.

- Geotechnical studies.

Multiple parameters are measured, and many of them are highly correlated. Having a sufficiently precise mapping helps in the application of predictive models of behavior or responses. In addition, information created can also be used for the dissemination of the cave and its complex.

2. Background

The importance traditionally given to the topography within speleology, is that any study following the discovery of a cavity requires a plane on which to base it. Hence the survey is one of the first tasks to be performed, and also constitutes the fundamental support to dump all subsequent studies.

At present there are different levels of precision as to topography relates cave. A representation of the physical environment is useful when it meets the purpose for which it was created. As in the mapping process, there is a range of accuracy values depending upon the instruments used:

1. Memory scheme, without scale, supported by descriptions.

2. Drawing at a guess, performed without measure instruments, with approximate scale.

3. Rudimentary plane drawn with data provided by a small compass graduated and rope or tape with divisions in meters.

4. Prism compass and tape.

5. Calibrated prismatic compass and clinometer and non deformable measuring tape.

6. Compass, inclinometer and tape, but with tripod.

7. Measurements with traditional tachometer.

8. Measurements with reflectorless topographic total station.

9. 3D Laser Scanner measurements.

Traditionally, topography was intended to obtain a plant plane or map, and at most cross sections and longitudinal profiles. The present article describes the methodology adopted to accurate geometrically characterize caves, estimating the error and to extract large amounts of spatial information to be introduced into the prediction models of behavior.

3. Methodology

This article shows the methodology used in the characterization of different caves of the Cantabrian Coast. The purpose of surveying was different in each case.

3.1 Choice of Terrestrial Reference System

To carry out a proper recording of information of the cave, in a homogeneous system, it is necessary to clearly identify the terrestrial reference system and projection, nowadays it is recommended to submit the documentation in the global reference system ETRS89 materialized by the National Geodetic Network using space techniques (REGENTE), as recommended by the Royal Decree 1071/2007 of 27 July (BOE. 207 Wednesday August 29, 2007).

3.2. Characterization of the protection environment

The task was carried out in different phases:

A) Creating the network of bases:

After choosing the reference system, a network of reference points is determined inside the environment protection area. The observation method used was differential observations both by static and real-time kinematic (RTK) from reference stations.

B) Geodetic surveying.

From the reference points we proceed to the measuring of mountain at the agreed scale (usually 1:2000).

For this purpose a combined method integrating GNSS-GPS in RTK mode and Topographic Total Stations was used.

3.3. Creation of the primary traverse

The primary traverse is observed; it is a go & back closed traverse which is later adjusted and compensated in each cave. The bases are generally materialized by steel nails.

The coordinate system used is the same as that used in the topographical environment.

3.4. Digitization of the caves

A panoramic 3D laser scanner phase measurement is utilized for the purpose. It provides an accuracy of 2 mm at 25 m, which allows us to obtain documents that meet the metric tolerances required.

In this phase, the following phases have been covered:

1. Position and rotation of the instrument
2. Spatial coordinates: value XYZ
3. Intensity: reflectance value of the material

The georeferencing is performed by using materialized previous topographic bases.

3.5. Preprocessing information: Clean and registration

In this step the field information is filtered and merged in a single model:

1. Cleanliness: It is removed any information that is not desired (noise), either manually or automatically.
2. Record: The position and rotation of the instrument for each scan is calculated in a specific coordinate system. This can be done through references that act as checkpoints.

3. Optimizing model: creating a homogeneous model. The model is structured and divided into parts for ease of handling and understanding.

The result is a point cloud, processed, free of noise, in the same reference system. Subsequently generalizes the information captured by reducing information in order to be possible to load into memory all the scans of both caves.

3.6. Information processing: Information extraction model.

A) Ground Plane

It is obtained by drawing directly from the point cloud. The map shows the outline of the cavities, the overpasses and underpasses, existing paths and stairs inside and other items relating to the urbanization of the rooms as points of light. It also contains the primary traverse axis used to observe the framework. All data is arranged in layers.

B) Longitudinal sections

The longitudinal section reflects in guitar diagram form details such as ceiling height, height from floor level of the room, partial distance, distance to the origin, etc.

Having continuous information of the full cave, permits that the longitudinal section may be drawn at any point, unlike with the traditional measurement methods.

C) Cross sections

They are created and dimensioned throughout the cave where there is a significant section change or in zones of special interest.

Since it is available a high volumetric density of information in the same reference system, it is possible to draw a large number of cross sections, and precisely know distance between galleries, even in case that these elapse in parallel. With other methods it would be very laborious to achieve.

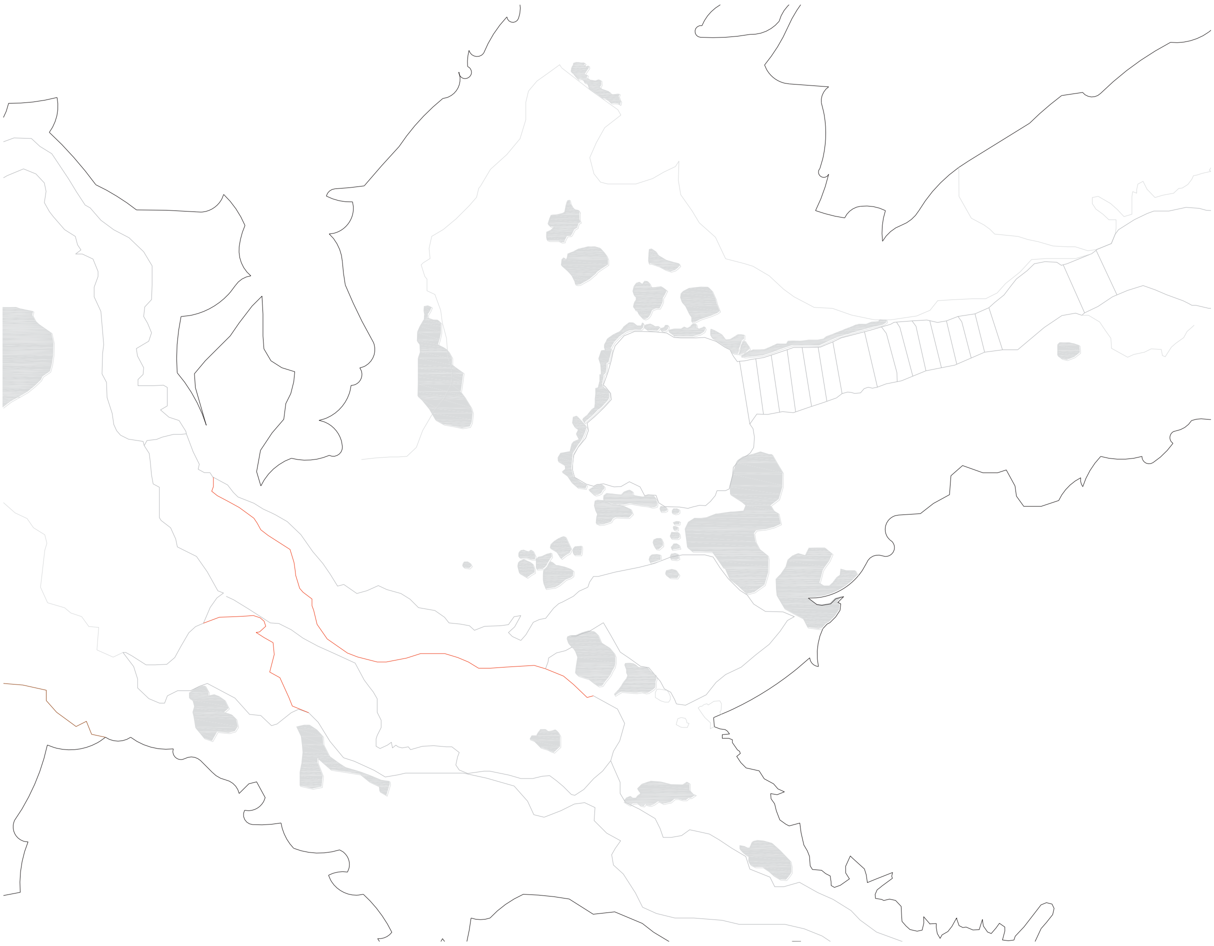

Figure 1: Detail of flat floor of the cavity.

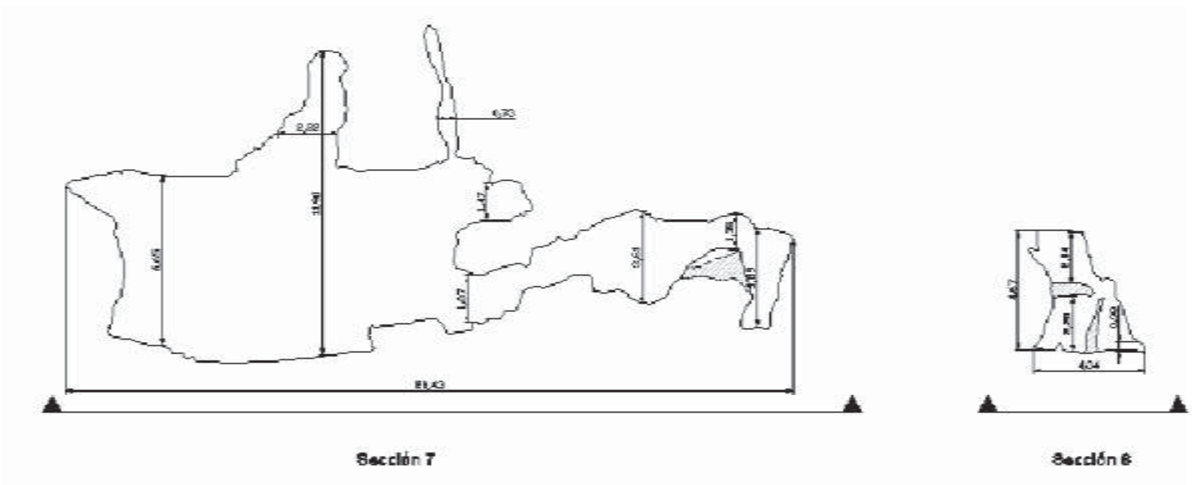

Figure 2: Cross sections detail.

D) Documentation galleries heights

It creates a series of maps with the heights of the galleries. These maps typically have a resolution of 5 to 20 cm.

E) Thickness of the roof.

It creates a series of maps with the thickness of the roof (distance between roof and surface) galleries. These maps usually have a resolution between 5 and 20 cm. From the viewpoint of computational geometry is the distance for the same pair of XY coordinates, between the surface elevation and the roof of the cave.

F) Contour level documentation

It can also be created a series of maps with contour equidistance around 50 cm for the whole cave. For details with microtopography requirements, equidistance can reach 1 cm.

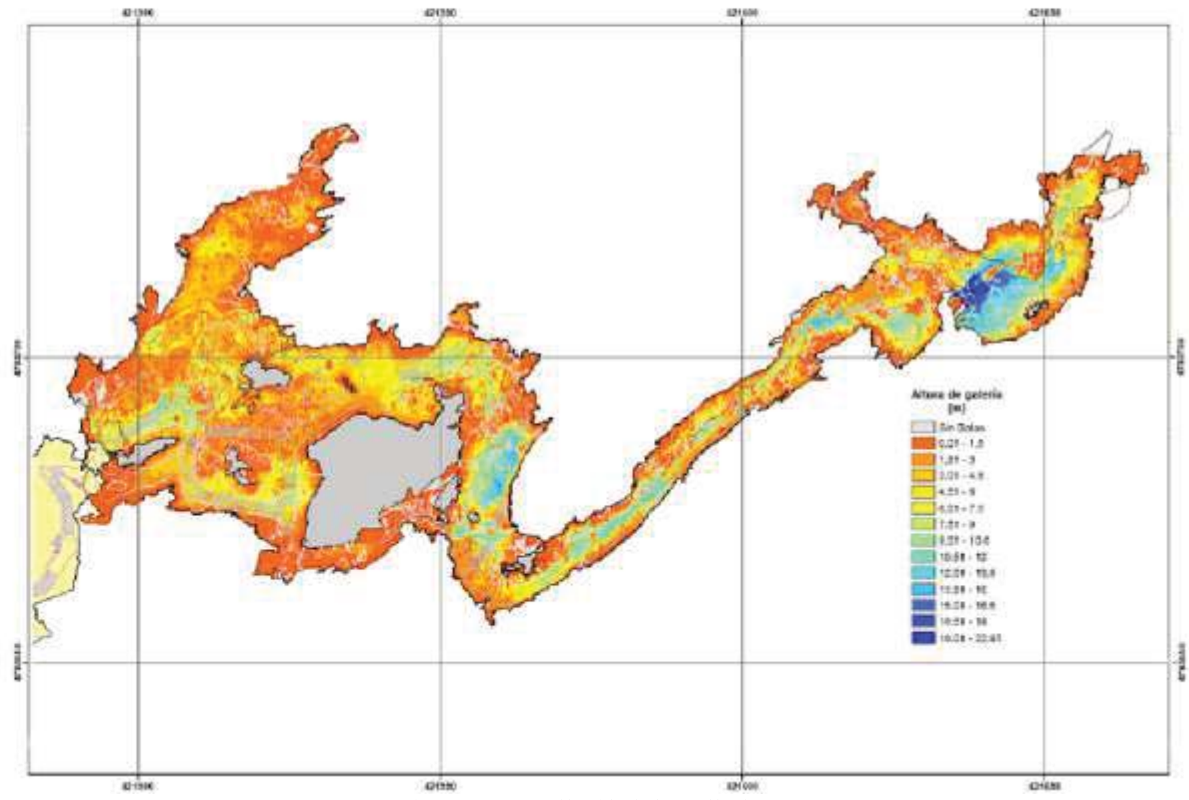

Figure 3: Detail of height galleries.

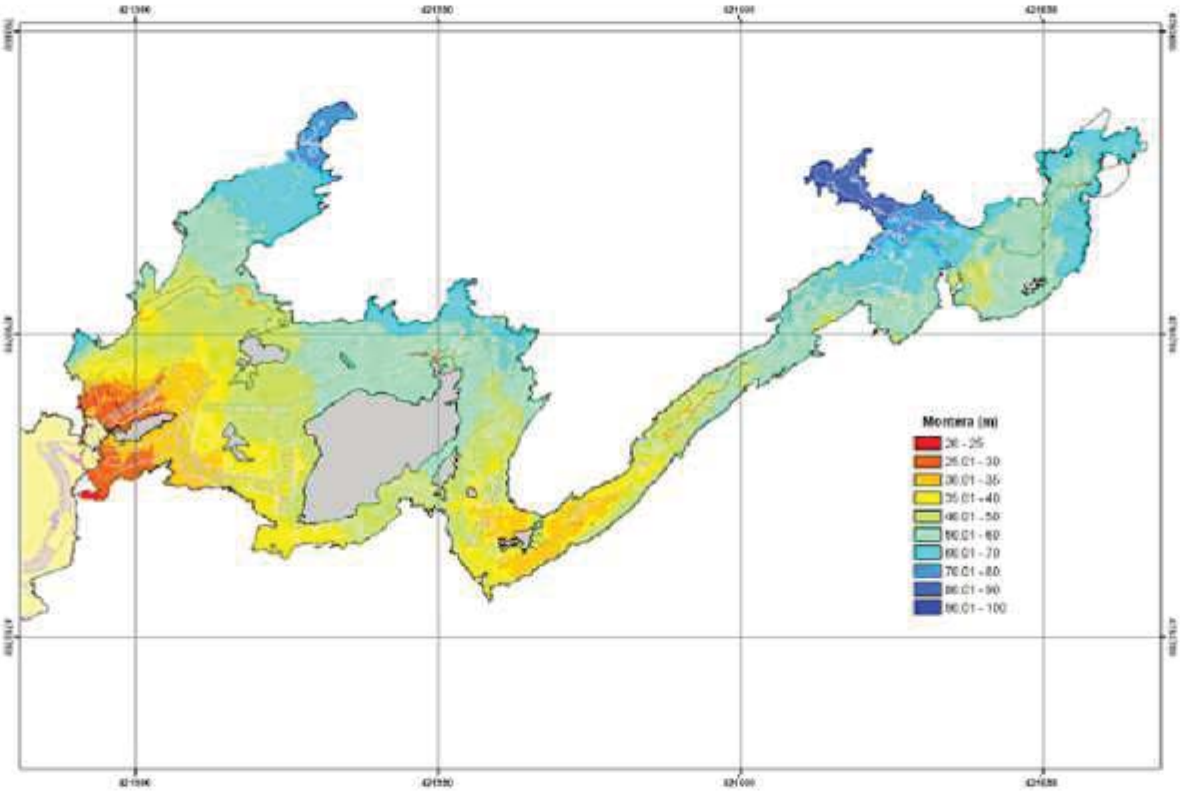

Figure 4: Thickness of the roof.

G) Generation of virtual models.

be used in virtual reality systems. Broadly the steps are as follows:

- Transformation models or points recorded by scanner to manipulable geometry.
- Construction of the 3D model.
    - Continuous Polygonal modeling.
    - Applying color with photorealistic textures.
    - Calculation of the realistic lighting model, that should be viable in real time.
- Development of the script of the application.
- Programming of the Virtual Reality aplication, that has to be real-time interactive.
    - Development of a script of the application.
    - Development of interfaces of the application.

- Visual representation by "High Level Shading Language" (HLSL) to obtain a realistic representation.

- Development and inclusion of multimedia elements to facilitate distribution of content from existing information

H) Generation of physical models

From point cloud data,

Sometimes an exact replica of the cave is needed. Point cloud data constitute the raw material to create it. The 3D model is 3D printed in parts, this pieces are mounted to constitute the basic support that later is decorated.

Figure 5: Generation of virtual models

4. Results

In view of the work it can be concluded that:

- It is possible to carry out a rapid, accurate and reliable measurement of complex elements such as caves or cavities;
- The information can be used to derive maps such as floor plans, contour levels, longitudinal and cross sections or three-dimensional analysis and calculation of heights or thickness of the roof by model comparison.
- The laser scanner, due to the operational readiness in field, the accuracy of data, the possibilities of representation and safety can be considered as an optimal tool for heritage.
- The combination of traditional methods such as polygonal geomatics surveying and GNSS (Global Navigation Satellite System) as with other modern 3D Laser Scanner allows documenting caves in a rigorous and safe way for the heritage.
- This information, can be used as a basis for managers to support their decisions and perform different simulations of predictive behavior processes within a knowledge based system.
- A novel departure cartographic documentation is the creation of virtual models, allowing the tourist exploitation of those resources, and avoiding damage by overuse. In short it is a solution that can achieve a balance between conservation and dissemination.

5. Conclusions

Looking ahead presents many challenges:

- Computational improvements: The study of systems of algorithms to accelerate the adaptation processes of initial data to create geometric data with topological structure.
- More efficient management: Create a Cave information management system, which can be used in decision-making about the same. A dynamic system, with thematic information that allows a real time monitoring.
- Scientific research: intercorrelation of more parameters in complex models that integrate information such as hydrochemistry, water microbiology, climatic, geotechnical and fauna.

- Promoting tourism: higher definition virtual tours. It will be possible to remove a smaller amount of data acquired in the initial phase, and get higher definition models.

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