

USING GIS FOR CAVES MODELLING AND ANALYSIS. THE STUDY CASE OF ANINA MINING AREA (BANAT MOUNTAINS, ROMANIA)

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Abstract: GIS started to be used also in caves' mapping, but the work in this area is quite less widespread as surface mapping. The aim of this paper is to present an approach to caves' digital modelling and analysis, using GIS and geovisualization techniques. COMPASS program is a software package designed for editing, processing, analysing and visualizing data on computer mapping caves. The programs allow input caves, reviewing data, obtaining statistics on caves, view plans from different angles on the monitor, and finally these views can then be printed. In this paper, we obtain digital models for endokarstic landforms situated in a karstic area in the South-West of Romania. We convert the Speleological data from analog into digital data and then obtained a virtual model for 4 cavities. Modelling karst cavities using GIS software require certain advantages and disadvantages. As advantages we can observe the fact that employing such a program can export a cave modelling in various formats and can include the function of spatial analysis in various programs, and the introduction of such objects in the Web Free and accessible. The main drawback to COMPASS program is given the simplicity and the limitation in modelling caves' galleries. This program gives the form of tubes, pipes, made from a variety of geometric shapes. For Anina Mining Area, where nowadays local authorities are trying to develop tourism as a branch of economic recovery, these digital data regarding the most important caves in the area could be very useful in the management plans and in the tourist strategies.

Key words: karst, GIS, cave modelling, Anina, Romania

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INTRODUCTION

Before the 90s and before the Geographical Information Systems (GIS) period, maps on paper were probably the most used method to study geospatial data. In the 90s the scientific visualization offered the term „*visualization*” (Kraak, 2002).

Goodchild (2000) talks about the limits of analog maps: (I) maps should be smooth, flat, (II) a map provides a single level of detail, (III) maps are static and (IV) the production of maps is generally slow. These limitations also apply to the 2D digital maps in his opinion.

Geographic Information Systems (GIS) are developed so as to represent real-world objects in cyberspace, virtual. Representations of the real world are made as close to the models created in the human mind (Bishr, 1998).

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Maps continue to be the base of navigation even in the virtual computer. A method of navigation closer to reality can be obtained by exploiting 3D data visualization, indeed, more sophisticated, and allowing users to interact with 3D modelled scenarios in the so-called „*virtual reality*”. This „*virtual reality*” is a tool that has as aim to provide users with a system based on a computer system that deals with real or realistic, having a live interaction with the data represented (Catarci et al., 2002).

Dimensional information needs grew and she continues to grow rapidly. Modelling reality with three-dimensional representations is preferred in practice because they increase the ability of scientists in the fields of Geosciences to analyse data and make determinations as accurate (Wu et al., 2008).

The methods provided by Geographical Information Systems offer great flexibility and customization possibilities in the design of modern maps. Geovisualization, as a tool based on GIS techniques bring new ways to design maps and representations of the world around them (Longley et al., 2005).

GIS started to be used also in caves’ mapping, but the work in this area is quite less widespread as surface mapping, based on software that is dealing with cave mapping and digital representations. Some works regarding GIS used in cave studies are done by Ohms and Reece (2002), Hung et al. (2002), Moyes (2002), Szukalski (2002), Harley et al. (2010).

In Romania, GIS studies in the field of the caves we may say that are missing: Constantin (1998) with a GIS database proposal, Artugyan (2010) with a study regarding the connection of two caves in the Anina Mountains using GIS methods. We think that there exist many directions were GIS methods could be used in caves’ studies. The aim of this paper is to present an approach of caves’ digital modelling and analysis using GIS and geovisualization techniques. We must be aware that any description of reality is actually an abstraction of real world elements. Representations of real-world phenomena and objects are abstracted or by proxy, or by simplification, either by ignoring some features.

STUDY AREA

The study area of this paper is situated in the South-West of Romania, in Caraș-Severin County. It is located in Banat Mountains, more precisely in a subunit of Banat Mountains called Anina Mountains, called after the town with the same name located in the centre of this mountain area. Reșița-Moldova Nouă Synclinorium is the place for classic getic sedimentary development and Anina is a town situated in the centre of this basin. In this area are thick sedimentary deposits (Mutihac & Ionesi, 1974).

The karst of Reșița-Moldova Nouă Synclinorium is considered as a prototype of suspended karst plateaus (Onac, 2000). The faults, that are indicating a higher density in the area, are favourable in the karstification processes. The orientation of these tectonic features is indicating the main drainage direction and act as boundaries between the main karst systems in the region (Iurkiewicz et al., 1996).

The field which represents the study case of this paper is situated in the centre of Anina Mountains. Anina Mining Area was the name given by Sencu (1977) for the area which is surrounded Anina town and it may be exploited by mining activities.

Anina Mining Area, due to large areas covered with limestone, is symbolized by many karstic landforms, either open or underground. There are sinkholes, uvalas, poljes, springs, potholes, blind valleys, sinkholes valleys, dry valleys and karrens. On the other side, the underground landforms are represented by a high density of caves and vertical shafts.

DATA AND METHODS

The data that we used in our study is based on materials as caves’ maps that were scanned and spatial referenced, GPS points marked in the field trips, topographical maps of scale at 1:25000 and aerial photos. Based on these materials we obtained the digital data regarding most important of the caves located in the Anina Mining Area. Our approach implies two perspectives: first - 2D perspective. This first perspective was done by overlapping DEM, topographic maps

or aerial photographs over those digitized galleries. To get those digitized galleries, previous caves' plans were Geo-referenced having as the source material the plans for those caves made by Vasile Sencu (1963 and 1964). The second perspective is about 3D modelling. It was based along the information pulled from the same cave plans, but this time as data of cave mapping in the field. After that, the data was introduced into a specialized program for karst cavities modelling, COMPASS Cave Survey. First, we scanned some plans for the most significant caves in this region. Then those caves were georeferenced, and digitized their galleries. This method was applied to obtain gallery's caves perspective on 2D and overlapping aerial photographs (figure 1a), topographic maps (figure 1b) and geological maps. These steps were developed in the ArcMap 10.

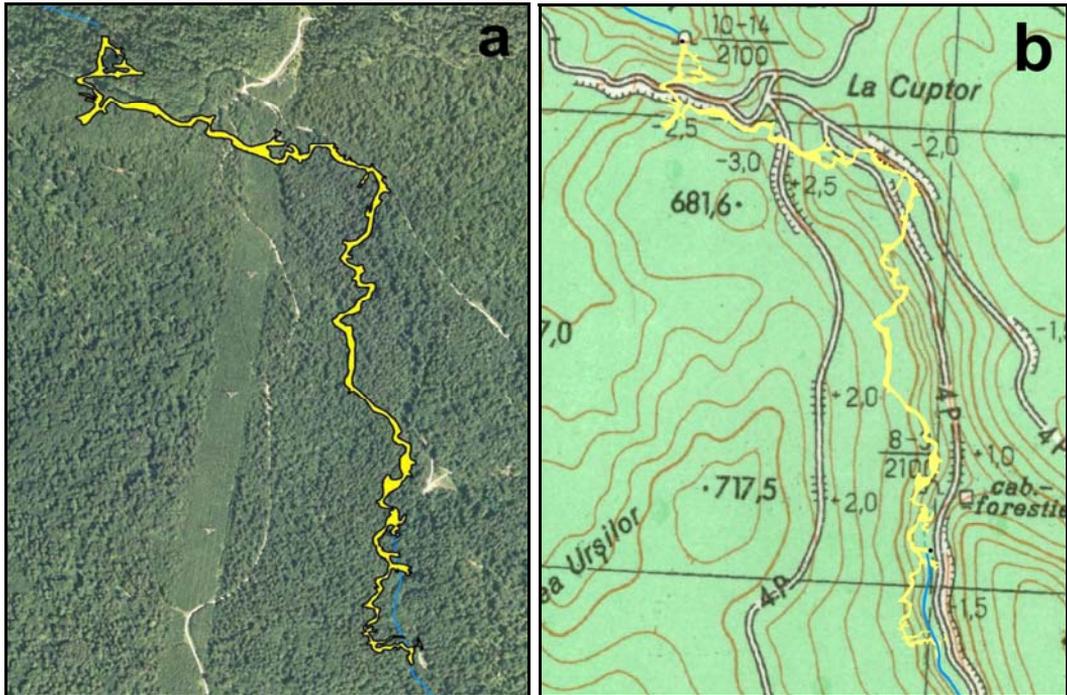


Figure 1. Buhui Cave overlapping aerial photographs (Source: ANCP) (a) and topographic maps (b) (Source: Military Topographic Directorate)

For three-dimensional perspective representation of karst landforms belonging to modelling choice of four of the biggest and most beautiful karst cavities Anina Mountains: Buhui Cave, Plopa Cave, Ponor Cave and Mărghitaş Cave. Obtaining three-dimensional models of the caves were done using the COMPASS program. COMPASS program is a software package designed for editing, processing, analysing and visualizing data on computer mapping caves. The programs allow input caves, reviewing data, obtaining statistics on caves, view plans from different angles on the monitor, and finally these views can then be printed. In this suite of programs were introduced mapping data extracted from the scanned plans of the caves mentioned above. After scanning the caves plans, mapping data extraction followed exactly as would be done in this field by entering data specific mapping underground cave in the table (see example table 1), and then, these data have been entered in COMPASS. Data mapping refers to the distance from the starting point (station) and one destination (visa), distance (calculated in meters) of the visa to the left and right walls, distance from the cave ceiling, the distance the floor of the cave (if visa section is an area with rocks or other obstacles to the floor of the cave), the angle towards magnetic north and inclination to the starting point (measured in degrees) (Povară et al., 1982).

Table 1. Example of a table for cave survey in the field

Station	Visa	Distance	Distance Left	Distance Right	Height	Depth	Azimuth	Inclination
0	1	13.2	3	4.1	2	0	234	0
1	2	2.8	2	0.3	1.4	0	139	0
2	3	35	1.657	2	0.45	0	209	-2
3	4	34	2.2	1.2	1.1	0.5	145	-4

To give a spatial reference, we chose for assigning coordinates of stations/visas (start/stop in a cave mapping) of points drawn in COMPASS program. We introduced four extreme points' coordinates and altitude relative to those points, and then we exported as shapefiles that cave model to use in ESRI programs.

RESULTS AND DISCUSSIONS

The results are represented by digital models (2D and 3D) for 4 of the most representative caves in the Anina Mountains. Three-dimensional models, with all the minuses given the difficulty of modelling the data from the underground are interesting results especially due to the working methodology. For 3D models we obtain these models in COMPASS software (figure 2) and then we exported into Shapefile format to be able to use it also in ArcScene 10 (figure 3).

In any virtual modelling we cannot avoid the introduction of errors in the model generated in the digital environment. The reality is very complex and especially karst underground environment. Although it was anticipated relatively large errors in 3D modelling caves, by correcting and reassessment of the process we managed to reduce the errors. This aspect was verified by overlapping digitized galleries in ArcMap with those polygons derived automatically by COMPASS software. We observe small errors in the model obtained automatically. This is due to the COMPASS program generates polygons and not smooth contours. The fact that the errors are relatively small and mainly generated within the COMPASS Cave Survey software could be notice by visual comparison between those two approaches manually digitized and automatically generated models, shown in figure 4a and figure 4b.

Modelling karst cavities using GIS software require certain advantages and disadvantages. As advantages we can observe the fact that employing such a program can export a cave modelling in various formats and can include the function of spatial analysis in various programs, and the introduction of such objects in the Web Free and accessible.

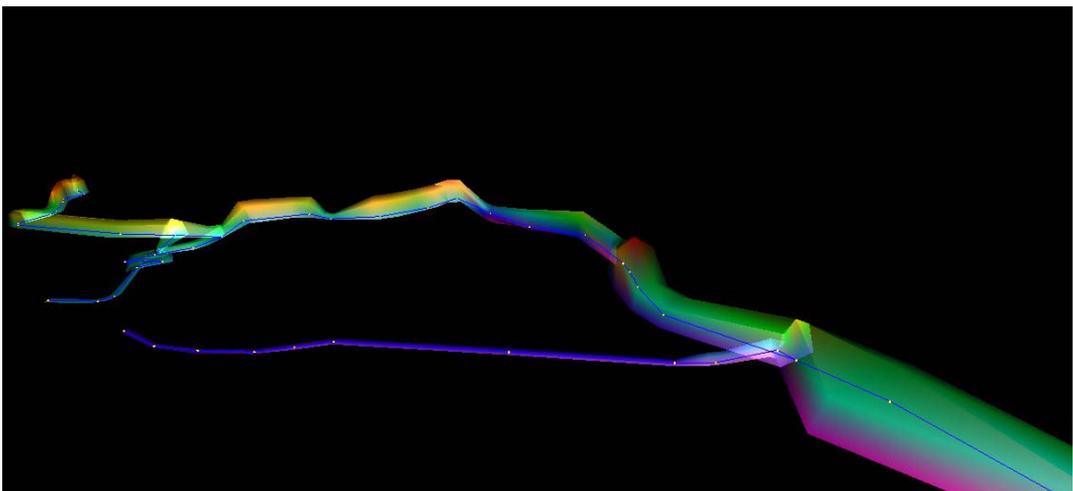


Figure 2. Plopa Cave - 3D model in COMPASS software (colours are representing the depth of galleries)

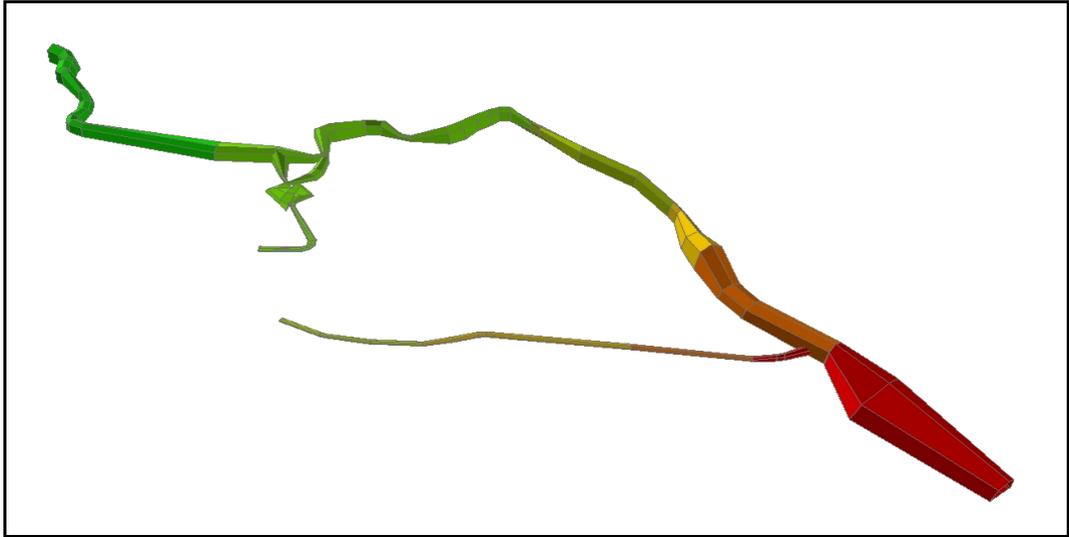


Figure 3. Plopa Cave - 3D model of in ArcScene 10 software (colours are representing the depth of galleries)

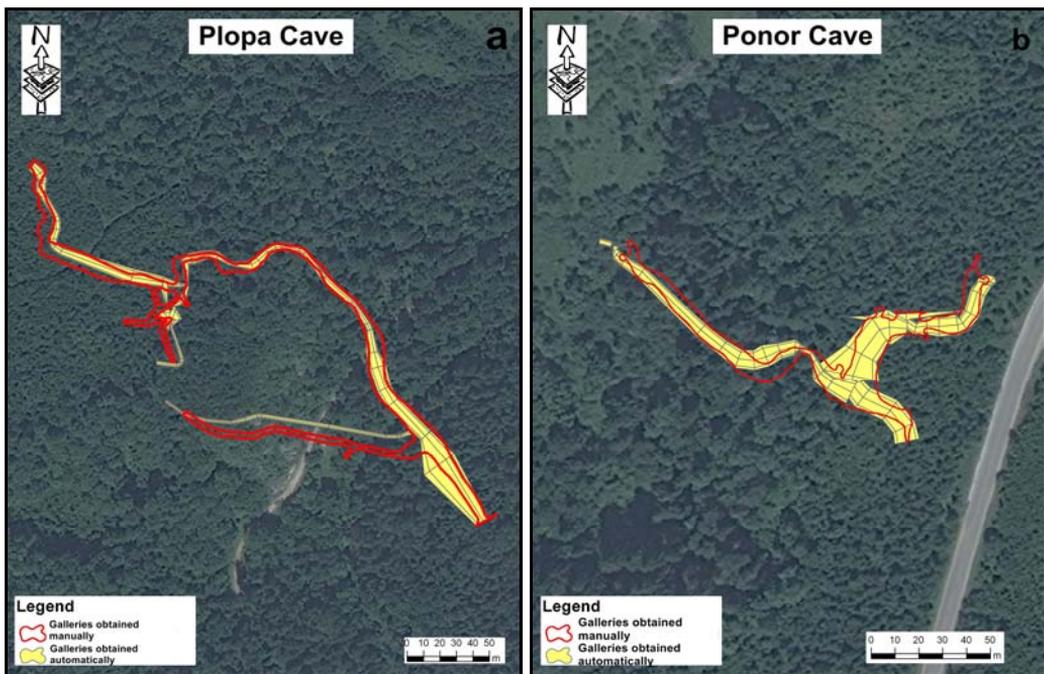


Figure 4. Differences between manual digitised galleries and those obtained using automatic modeling: Plopa Cave (a) and Ponor Cave (b)
(Source of background image: ANCP)

The main drawback to COMPASS program is given the simplicity and the limitation in modelling caves' galleries. This program gives the form of tubes, pipes, made from a variety of geometric shapes. Due to these limitations in modelling, the visual aspect of caves is not the most aesthetic, but considering the difficulty in modelling the subsurface can say that is a success that can shape karst cavities using a computer and especially that we integrate these models in various other soft wares for analysis and visualization.

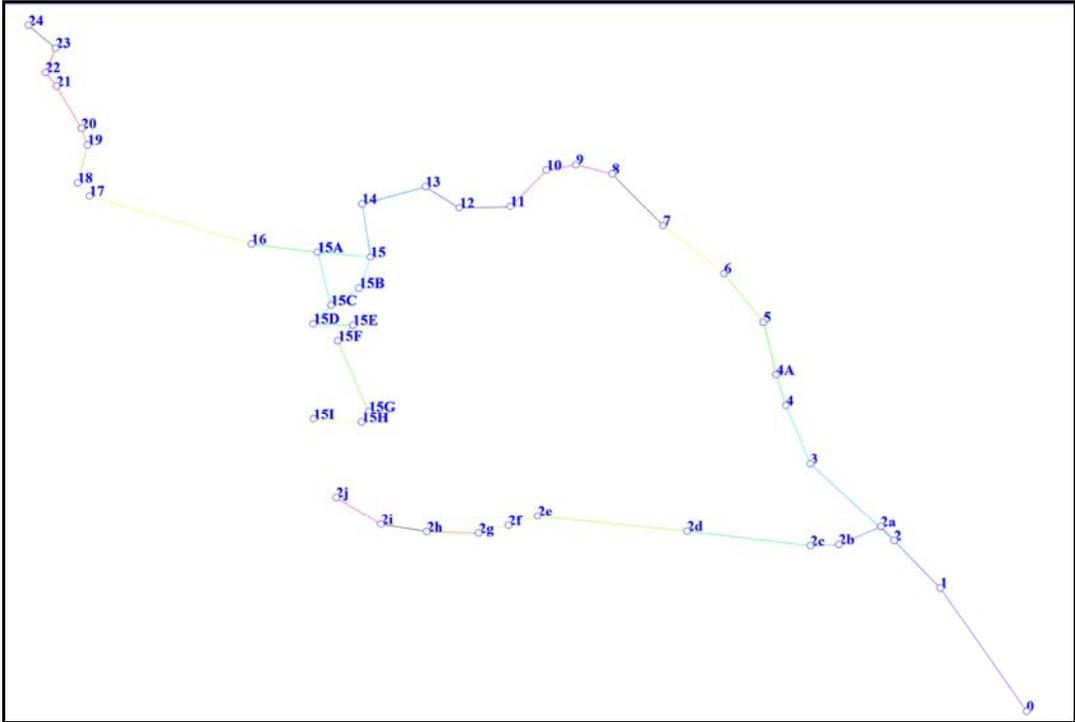


Figure 5. Plopa Cave - distance from entrance in COMPASS Software

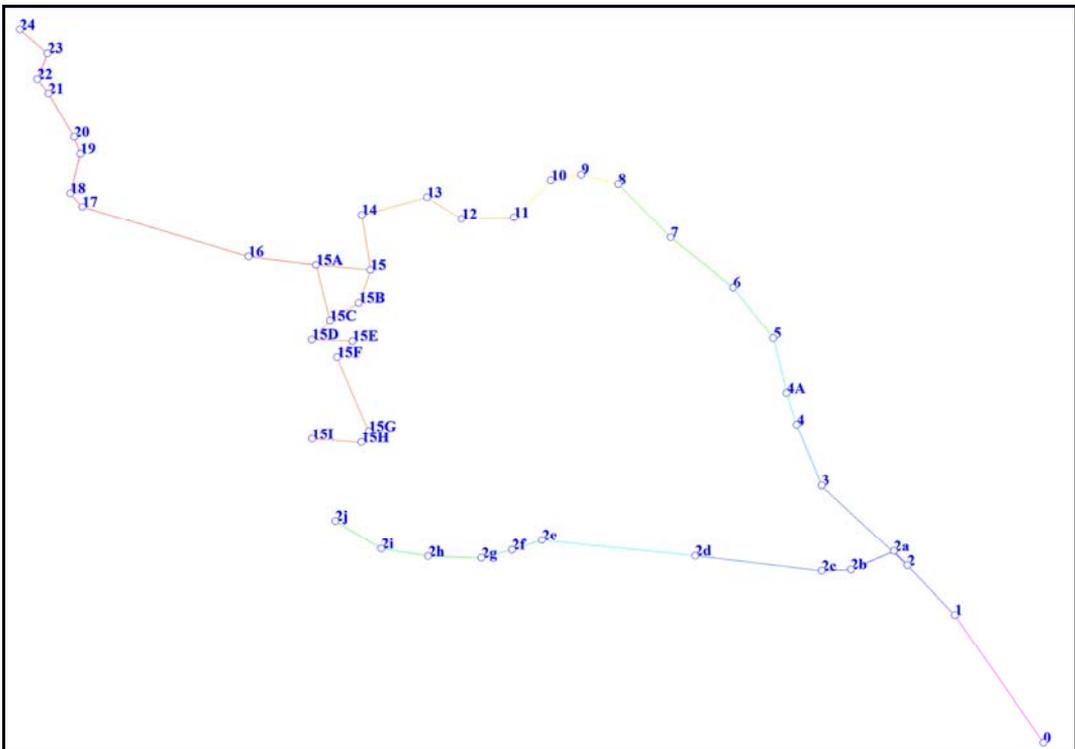


Figure 6. Plopa Cave - depth of galleries (pink is less depth - red is the maximum depth)

With the COMPASS program, we can exploit various approaches from digital modelling perspective for caves. These functions of the COMPASS software can analyse various perspectives develop galleries of caves. Subsequently, these analyses related to distance from the entrance (figure 5), the depth of cave's galleries (figure 6), cave morphology, evolution, can be implemented in developing management plans for these karst cavities and to tackle analysis regarding land use in the gallery development to avoid certain threats that are rising based on human activities at the surface.

Geographic Information Systems have evolved from isolated GIS to systems with a high degree of interoperability. The original purpose of a Geographic Information System was to store, manipulate and maintain data that is directly related to the mission system users respectively, which were created data without question the data exchange between systems. But increasing need to share information with other institutions and reduce costs, it was the creation of tools to support not only the distribution and sharing of data, and interoperability between data and services (Laurini et al., 2005).

The outcomes can be accessed also in Google Earth. The representations were loaded in. kml and. kmz on a Google site and following the instructions on the home page of this site, you can access representations of karst cavities. The link to the caves on this site is: <https://sites.google.com/site/caveskml/system/app/pages/recentChanges>.

CONCLUSIONS

In this paper, we obtain digital models for endokarstic landforms situated in a karstic area in the South-West of Romania. We convert the Speleological data from analog into digital data and then obtained a virtual model for 4 cavities. Besides, we upload some of our results in one Google site, both in JPG format and kml format, with the main idea that open those caves in Google Earth. Based on this work we are able to observe the difference between manual representations of this underground landforms and the automated process. Having these digital models we are able to use those ones in more complex spatial analysis. We can integrate those models in analysis combined with topographical maps, aerial maps or Digital Elevation Models. In this way we are able to realize an integrated analysis in a karstic region, studying both the surface and subsurface landforms. Despite the strengths of GIS techniques, the quality and quantity of information available when we require shaping reality is real important. This makes the quality and character of data had some drawbacks that led to some limitations in this field.

3D caves modelling using GIS programs involve some loss of information, quantitative and especially qualitative. Quantitative, when we have a plan map in centimetres and then we should convert it into meters. There we lost at every transformation some units and certain errors will occur at the end. Qualitative loss covers issues on how to present the result of these three-dimensional modelling. The existing software currently on the market turns the cave into a burrow, in a series of tubes. And the most attractive elements of the caves can not be placed into a „pipeline". All the previously mentioned limitations of the study may be targets of future studies, the objective of developing new solutions for data acquisition and modelling caves using GIS-techniques and geovizualisation.

In our future work we intend to enrich the number of caves in the digital approach, and also to develop new ideas regarding caves modelling and representation using GIS-techniques and geovisualization. Our study could be very useful for caves' administrations in the study area and also for tourist's perspectives regarding these caves. Besides, when you have a digital model, you are able to update this model with some new discover regarding the cave's galleries, meaning less time consuming to draw the map from the beginning. This approach could be very useful for caving associations that are managing these sites. With such digital data regarding the location and development of cave's galleries, territorial planning in karst areas could be easier done paying attention to the most vulnerable sites in these regions, naming here caves and their speleothems.

For Anina Mining Area, where nowadays local authorities are trying to develop tourism as a branch of economic recovery, these digital data regarding the most important caves in the area could be very useful in the management plans and in the tourist strategies. Part of our results could be very useful in tourism promotion of the caves in the area as geomorphosites (Artugyan, 2014) because part of these results could be easily understood by the general public, due to the access using interfaces as Google Earth or ArcGIS Explorer Online.

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