Cave Information System

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SUMMARY

Caves are such underground objects, which are isolated from the outer world since the beginning of the prehistoric ages. The dust-free and partly weather independent environment allowed the formation of a very special flora and fauna. The geologist can look into the secrets of the Earth building the history of the past. From other point of view, caves are important for tourists; many people wonder the world of the eternal night. The changes on the Earth surface and the water pollution have effect on the sensitive balance of underground world. That is, why it is so important to make complex modelling systems on the caves, which show the spatial processes of relationships.

The first step was to find the optimal measuring method to determine the coordinates of the cave entrances. The optimal solution of this problem is the GPS. How to use the GPS and process the raw data obtaining coordinates with sufficient accuracy. These are the primary topics of my study.

The second thing is how to survey the underground world. Primarily we use traditional instruments; tape, compass and sometimes optical theodolite. Nowadays, total stations and laser scanners are the most up-to-date instruments to carry out precise and large number of measurements. These technologies are discussed in the second chapter.

The third thing is how to visualise the results of surveying. I used the so-called *Polygon* software, which allows making cross-sections, ground plans and three-dimensional visualisations. That will be presented in my study through examples.

In the last chapter of my study I will show some opportunity, how to build the spatial information in a Cave Information System. To realise this task I used the *GeoMedia 5.1* software building a complex cadastral system of caves including their direct vicinity as well.

INTRODUCTION

In the GIS Sciences were going off dynamic changes in the last few years in Hungary. The people recognize that the covering of the natural sights can be achieved only with close co-operation between the different civil services. One part, and one lever can be in this problem-solution the geoinformatic. Building a complex information system is important for all services, because these systems can be a uniform base for all technological and economical planning. Not only the national parks and nature conservation areas are claiming up-to-date digital maps, it is also important for all local governments, technological and economical firms.

The caves are especial objects in this circle, because the most Hungarian caves are not in safety. The bluntness and fear of the common men are destroying them; this moment is maybe the last, when we can do something to safe them. The primal assignment is building a cadastral information system about the measured three-dimensional data's of the caves and the mountains, where we can find them; to get acquainted with their spatial distribution, synthesis and the harmful environmental effects. The accent is on the spatial data's, because a good decision can be born only than; when we well know the coherence between the underground world and the surface of the Earth.

I was build two cadastral information system: one about the caves of the Keszthely-mountain, and the other about the caves of the Tihanyi-peninsula. The most caves in the Keszthely-mountain are limestone caves and basalt-caves; and all the caves of the Tihanyi-peninsula are non-karst caves, they are about gejsirit. Make a map about a karst-area, or a non-karst area; measure a karst-or a non-karst cave are needed different methods, and build an information system need different attribute data's. The whole workflow I can partition to four steps:

1. Determination of cave entrances
2. Surveying the underground world
3. Making a map about the measured data's
4. Building the complex information system

2. DETERMINATION OF CAVE ENTRANCES

The most caves are able to determine the coordinates of their entrances with the Global Positioning System. The entrances we can identify only with sub-meter accuracy, so it will be adequate, when we use a GPS-receiver, that is appease this assumptions.

In the summer of 2001, I was investigating the optimal measuring method in the area of the National Park of the Balatonfelvidék. I was looking for the optimal measuring time and processing method in many investigating-models. Approximately I was measuring 300 cave entrances, with four GPS-receivers; the Leica-500 was a receiver for geodesy, the Trimble ProXr for GIS measurements, and the Magellan Tracker and Garmin Etrex for navigation measurements. Auxiliary instruments were tape, compass and a Leica laser distance-meter. Often we can not make an instrument setting off in the entrance, only a few meter distances from it. Measuring the direction between the instrument setting off and an entrance we use a compass, and measuring the distance, a tape, or a distance-meter. Using this was difficult, when the Sun was shining, because we can not identify exactly the place of the laser-point. We measured slope distances, but for the sake of the short distances, it was not necessary to reduce these measured values to horizontal distances. For the sake of the trees or the hang over rocks we can measured in most cases only the signs of four satellites, so we had to afford the measuring time from the optimal 10 minutes to 20 or 25 minutes.

Processing the measured values, we investigate many opportunities. We try to process the coordinates from different permanent stations (BME,Penc, Eszék, Graz, Bratislava), with code-method, or with phase-method, with precise-or broadcast ephemeredes, measuring 1-5-10-30 minutes, on 4-5-6-8 satellites. We measured the caves also in the summer, when the vegetation were high, and also in the winter, when only the stocks and arms of the plants, and the hang over rocks were uncovering the sky. We investigate the loss of lock, of satellites near the horizon or the zenith.

The short summary of the results:

1. The determination was able the Leica and Trimble GPS too, but the accuracy of the navigation receivers were not enough. The navigation receivers are only able to look up the entrances, when we know their coordinates.

Fig 1. : Determination of a cave entrance

2. The optimal measuring time was 10 minutes, and it is practical, to process the coordinates from the nearest permanent station. Processing with the phase-method or

with precise ephemeredes is needless; it is adequate to calculate the coordinates with the code-method and with broadcast ephemeredes.
3. It is practical, to set out the receiver insofar high, as possible, because of the uncover-effect of the trees and hang over rocks. The investigations were demonstrating, that uncover the satellites near the horizon are making smaller mistakes in the processing, like uncover some satellites near the zenith. The most important effect of uncovering are not making the leaves, but the stocks and arms of the plants.
4. Between the WGS-84 and the Hungarian EOV, it was enough to use a same general transformation parameter file for the whole area of Hungary; using some troposphere-or ionosphere-model was not necessary.

3. SURVEYING THE UNDERGROUND WORLD

Traditional instruments (compass, tape) are the wide-used instruments in cave surveying. The surveying-method is the traverse or polygon surveying, and the polar method. After the surveying, the data's needed adjustment and error calculations, which equations are well-know for the seasoned surveyors.

3.1. The Future of the Cave Surveying

Nowadays, total stations and laser scanners are the most up-to-date instruments to carry out precise and large number of measurements. The laser scanners make more thousand measurements per seconds; as it were scan the wall of the cave. The measured values are able to import almost to every desktop mapping software. Adapt the values in a three dimensional studio to a digital terrain model is only a question of the adequate knowledge of the software. The perfect solution is, when we assign a database to the map, so we are be able to store a lot of attribute data's. For an example: the colour and healthy of the dripstone, esteemed lifetime. The accuracy of the laser scanners exceed the needed accuracy of the cave surveying; only their cost and size arrest their permeation. The accuracy of the angle-measuring is +/- 60 micro-radian, and the accuracy of the distance-measuring is in average +/- 6mm/50m. Especially interesting is the adaptation of the ultra speed phase-based scanners. Their range is relatively small, but their continuous laser-light allowed faster scanning-speed. (From 10 000point/sec to 50 000point/sec) Their viewing angle is 360*310 grad; what is especially good for the inner-measuring of the cave-rooms. A lot of scanners are able to setting out to a point, and measure the instrument height, make an orientation; this is a condition of the measuring in a local coordinate-system. When we have a correct projection equations between the local projection system and a so called country-wide projection system-in Hungary this is the EOV- we can edit a map a national projection system. Adopt effective;
manufacturing accessories the measuring will be fast and dependable. From the any manufacturing accessories the most nimble are the adaptation of the ball-links. For an example: FARO Laser Scan Arm. After the instrument setting we could be able to rotate the scanner round it's vertical axis, so we can eliminate the effect of the 310 grad viewing angle.

Fig 2. A laser-scanner in a cave
(Picture copyright Yorkshire Post
Newspapers)

In the last few years the geodesic measuring instruments go throw a heavy development. The total stations will be always better, their automatisation will be ever in higher level, the spectrum of the surveying works will be more colourful. The development of the GPS-receivers allowed the real-time measuring methods, so on the field we can get in real-time, phase-processed, centimetre accuracy coordinates. I the first time it was feasible only with allowing an own basis-station, but after the development of the GNSS-infrastructure, we can use for this works the network of the permanent stations. The top of the developments is the Smart-Station, the total station combined with a GPS-receiver, what allowed easy the execution of complex geodesic works.

In the cave-surveying beyond the surveying of the inner rooms, it is also important to measure the representative points of the closed area of the entrance. The geologist and geographers can draw a lot of inference about the evolution of the cave, when they know lot information about the karst-shapes of the surface of the mountain. The flow-direction inspection of water-courses, the relative post of the underground objects in relationship to the karst-objects on the surface give us information, in which area, in what direction the undiscovered cave-arms to find are.

Nowadays the spelunkers are using traditional surveying instruments. The directions are being measured with a compass, the distances with tapes. For the sake of the surveying methods and surveying instruments, especially by the big horizontal and vertical caves, the number of error step over easy the margins of error. Surveying the close area of the entrance failed because of financial and temporal aspects. Compass and tape is not enough for the correct surveying. A lot of underground objects are undiscovered, because we do not know well the coherence between the extant cave-arms and the surface. This is important, not only from the aspect of the natural conversation, this is also important for the tourism and the hygiene. Thinking the Abaligeti-cave in the Mecsek-mountain, or a Kórház-cave in a Bakony-mountain; these caves are very important for the lung troubled people!

The correct solution for this problem is the Smart-Station. We do not need control points near the cave-entrance, using a RTG-GPS method we can execute the procedure of the control-point densification. Determine a coordinate of a single point takes only a few minutes, so we

Fig 3. Smart Station

can determine a large numbers of points, in view of the shape of the surface, and the cutting-off. Lean on these points, we can measure a regular network of detail points, which are in essence a three dimensional point-troop, which can be the input data's of the foreign processing and visualisation. After the control-point densification on a separate antenna-pole the GPS-receiver can measure alone, and the total station too. We can start the work in two different part of the scope of the activities; this is very auspicious from financial and temporal aspects. The issue of the surveying can be a level-line map, which shows the inclination relation of the surface, or a Digital Terrain Model (DTM), which is accreting the horizontal and vertical information. When the cave is not too strait, then we can use the total station under the ground. In one workflow we are able to measure the polygon-points, and the cross-sections, because of the laser-distance meter we do not need a reflector tape or a reflector prism. We can write own programs for the surveying, when we know well what we need to measure, a program can control self the measuring like a robot-theodolite. We get in shorter time much more information like before, what is very auspicious from all point of view. So far the caves were illustrated in section, ground plan or in a stretched section, but this new surveying method allowed the illustration on an isometric or plastic map. Both map is using a three dimensional coordinate system, so they are the best, and most beautiful visualisation methods of the caves.

4. MAP MAKING

The most elemental documentation of the surveying is the map. They visualize the spatial range of the cave in relationship of the surface. The map is also important for the effective and purposeful explorations. A cave-map, like a geodesic map is showing the reality in scale, ground plane after a generalization. Like the caves are three dimensional objects, the visualization in two dimensions is not enough; we favour the three dimensional mapping methods, or plan-maps with many attribute data's. The most cave-maps are sections, where the duct width on the map is meaning the real width of the duct. When the cave is a vertical cave, it is better to show it with a projection to one or more vertical plan. We can illustrate the cave with an isometric, axonometric method, where we replace the cave-arms with prism, or by the hydrotermical caves with ball-chambers. When we want to make a perfect map, we must know very well the kind of maps, which the spelunkers are using.

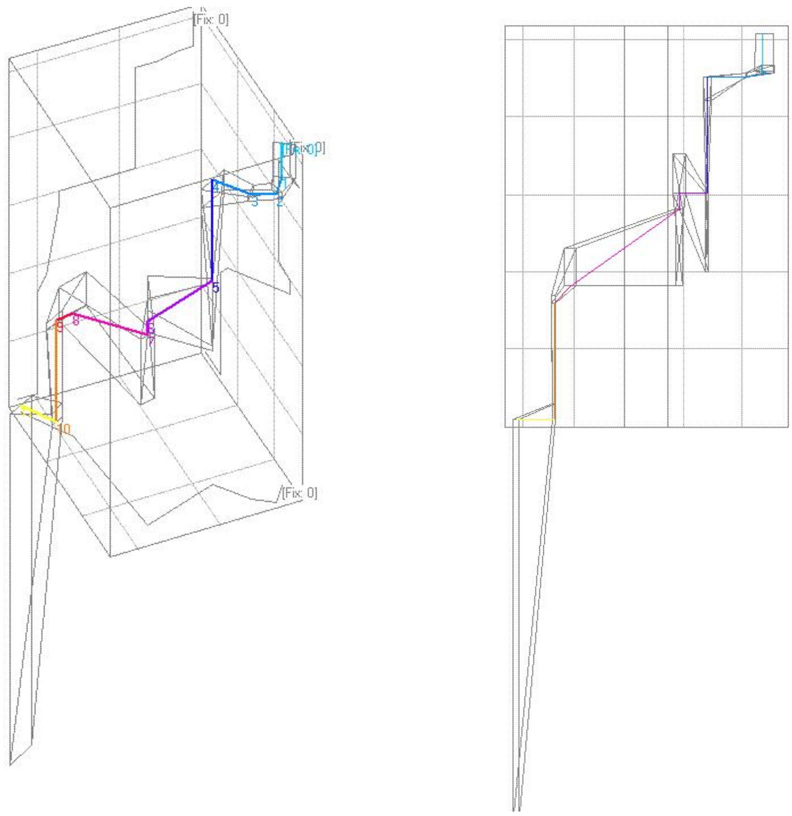

Fig 4. Digital Model of the Wind Cave

5. BUILDING AN INFORMATION SYSTEM OF CAVES

The most effective, multi-faceted form of publishing the collected, spatial data's of caves is the information system. It contains a lot of geometrical and attributes data's, from a diversified database are we able to make simple or complex queries. The systems are capable for publish them in the Internet, so they can appease wide user claims, from the scientific interesting to the tourist claims.

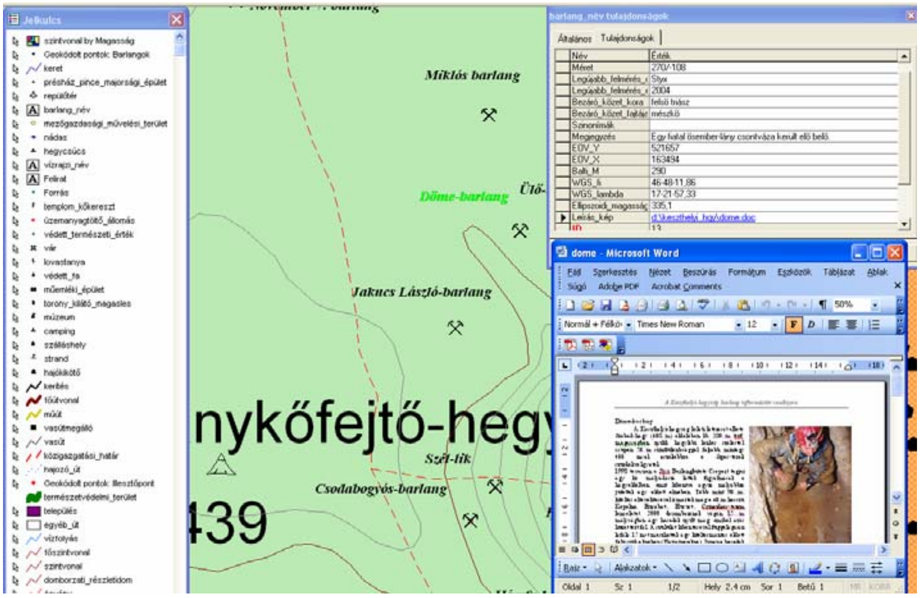

Fig 5. The information table of the Döme-cave

Building an Information System of caves, I can distribute to two steps. The first step is shaping the map, and the second step is compiling the descriptive data's.

For shaping a map, it is very important to choose a good basic map, with adequate contents. We have to aspire, visualize all important detail, which are representing the reality model of the Earth, without congestion. The most capable for this exercise are the Hungarian topographical maps in a scale of 1:25 000. It is easy to handle able them, and their contents are adequately circumstantial.

After choosing the adequate map-section, we must scan it with a professional scanner. For this exercise we can use a flat-bed plotter or a drum-plotter too, but I think that the drum-plotter is better. In this plotter not the sensor is moving over the paper, but the paper is moving with help of some rolls. It is no positional error, and a plotter requires only a few places.

Finishing the map-design, the next important step is collecting the attribute data's. I mean, that this data's are deputizing the real values of an Information System. Important view point of the data collecting was collecting numerous data's about the cities, towns, villages and natural sights; in a given region among the covering values are not only caves, but cultural and ethnographical values, too.

The operative part of the documentation was refilling the attribute tables of the caves. All table contain the following: cadastre ordinal number of the cave, the name of the cave, length, deep, name of the researcher spelunker club, the year of the last research, type of the rock, age of the rock, other ethnographical name of the cave, comment, EOV_Y, EOV_X, Height (Baltic-see), WGS_fi,WGS_lambda,ellipsoidal height, description, pictures, maps. These informations are in a hyper allusion, under the name of the caves.
Out of the cave's data's, valuable things are in this Information System the descriptions of the cities, towns, villages and natural signs. They can be a start point for an interesting family excursion, too.

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BIOGRAPHICAL NOTES

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