SUBTERRANEAN-MODELLING
FROM PLAN TO COMPUTER MODEL - ENTERING THE 3RD DIMENSION

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ABSTRACT

The German Mining Museum is mainly working on the exploration and examination of ancient mining. There for it is important that a precise map is drawn up where the results of e.g. an excavation or the ancient working traces are documented. Sometimes there is already a 2D plan and one wants to "add" or improve more information to the plan. Very soon a plan becomes confusing e.g. when passages intersect on different levels or (interesting) parts are hidden by others in the respective projection.
In this article possible workflows will be shown, starting with the measuring of cross sections with various equipment (optical, electro optical). Further more different possibilities of how to orientate the single sections are discussed and the construction of the 3D model is revealed by using AutoCAD and 3D Studio MAX. Finally leading up to the following article, an example of an information system, built in 1999 will be demonstrated as well as some visualisations are examined.

Subterranean measurement, respectively subterranean documentation is a very special and difficult topic, which is to be handled of course with special (technical-) solutions. The very detailed requirements are pointed out and (our) solutions are described.

MINES IN 3D

In mining archaeology it is often not enough to record the excavation exclusively, but also the mine surrounding it. All objects like graves, cellars, caves and mines, do not only reveal their information on the ground but also at the side-walls and at the roof ridge. These irregular (surface) structures can not always be simplified in a plane (ground plan, section plan, etc.) therefore it is necessary to keep the information e.g. in a 3D model. The advantages of having a computer model in addition to photos, videos and plans must not be pointed out separately, but in mining archaeology you finally get the possibility of:

- calculating the volume (how much material was extracted)
- looking at your model from outside ("through the rock")
- constructing any section you wish
- preserving the information of roof, walls and ground in one "plan"

Having come to the conclusion to document your object (-structure), 3-dimensionaly, you must decide how the data is to be captured. Beside the well known and often used "laser scanning", we are glad to present an alternative method, the so called "profile scanning".

These two scanning methods have in common that simply spoken a laser beam measures the distance to any object in a range of 20 cm to 300 m with the speed of light.

Just pointing out some of them, the main differences between those scanning systems are, that a laserscanner is put up a tripod, providing range, horizontal- and vertical angle (3D) and signal amplitude, while the profile scanner is a 2D handheld system. 2D means that in addition to the distance only one angle is provided so you get a flat shape. Furthermore a laserscanner measures about 1,000 times as much points as the profile scanner. The operating range of most laserscan-

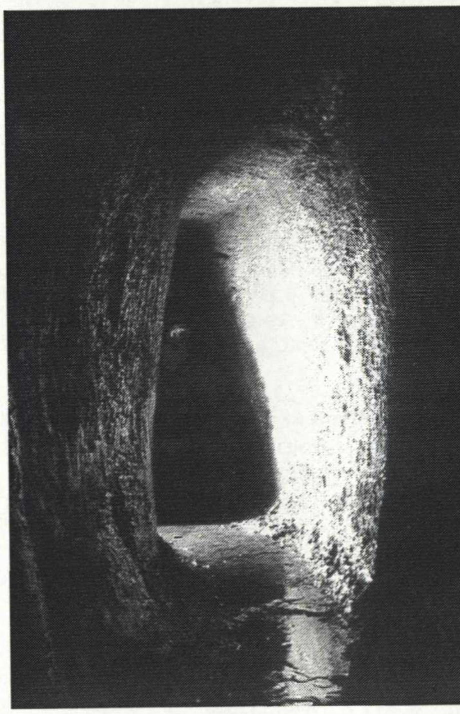

Figure 1 standard photography

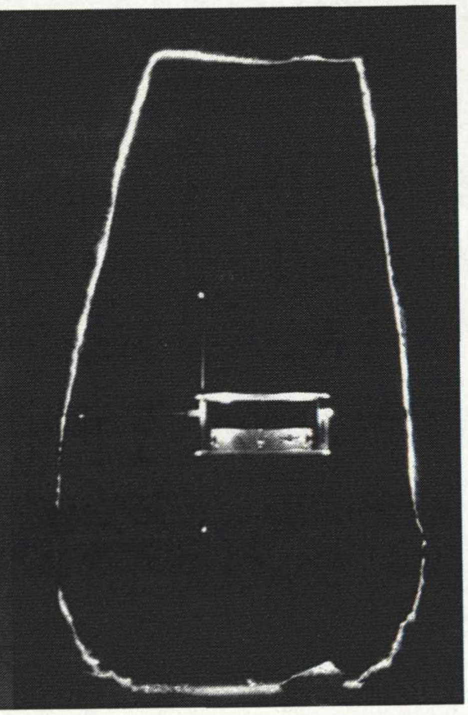

Figure 2 cross section of the same situation as figure 1 ners start at 2 m which is of course to much for narrow ancient mines.

Measuring Cross Sections

The measuring of cross sections is suitable wherever you work in small spaces (e.g. between two walls) or in stretched structures like galleries. There are two main methods of measuring cross sections

1. an optical one[1]
2. an electro-optical one

The optical method is operating by taking pictures of a light-bar emitted with a flashlight. The light-bar is an app. 5cm width shape covering the walls (Fig.2).

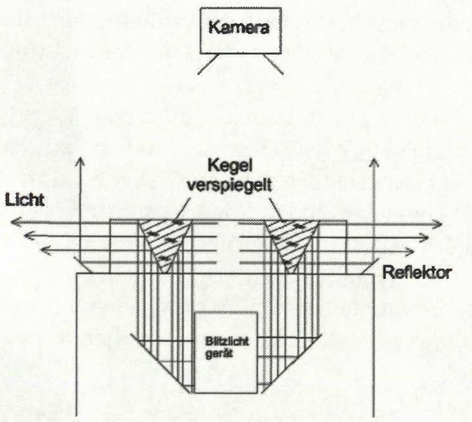

Figure 3 flashlight device

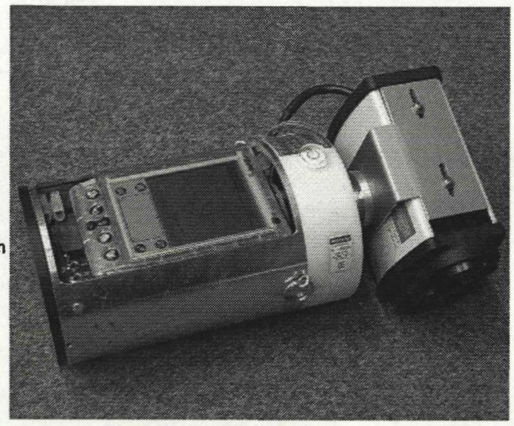

Figure 4 laser scanning device

The little light spots next to the device (visible in the second picture) are put up in a known distance, giving the scale while digitising the photo. There are several limitations to observe using this method. e.g. you always have to get far away enough from the cross section to take a picture of it, which can be limited by the available space and the focal length of your camera. This is the reason why (and because of other limitations) the Deutsches Bergbau-Museum Bochum in association with partners from speleologie[2] has developed a device which measures a cross section electro optically.

The Handheld 2D Scanner

The frequency of the laser is 100 Hz. During 3 seconds the laser rotates about 360° with the result that a single cross section consists of 300 vertices.

The data is sent to a Palm IIIe handheld device where it is calculated and displayed. The user is now able to check the scan for errors, caused by e.g. less reflection or invisible parts of the section.

To built up a 3D model you need the position where each cross section was captured.

Therefore a measuring tape is put between two polygon points with known coordinates during the measurement. The particular position (read off the tape) of taking the scan is input manually into the palm device (Fig.5). Holding the scanner-device horizontally and parallel next to the tape the scan is started and 3 seconds later the cross section is displayed on the Palm.

After transferring the data to a PC, the computer can put the shape nearly in the right position in (virtual) 3D space. Nearly, because you slightly have to adjust the horizontal and vertical position. This is because you may not always have put the profile scanner right next to the tape, but due to local circumstances differed from this specification (but you always have to put up the device horizontally and parallel to the tape).

What to do with the Data ?

The following figures show the recorded data first being reduced from 300 points to app. 30 points. The reduction of the data is very important to keep the amount of polygons of your 3D model as low as possible, and thus manageable. Second the spline has to be smoothed which gives the structure a much more natural appearance and also eliminates "jumps" between two vertices caused by the measurement error of the laser scanner. As you can see inFigure 8, the tape, which was put between two polygon points, can be identified as a peak in the blue shape. You also see the vertical and horizontal offset of the measuring tape "connecting" the point of origin of the profile scanner with the tape.

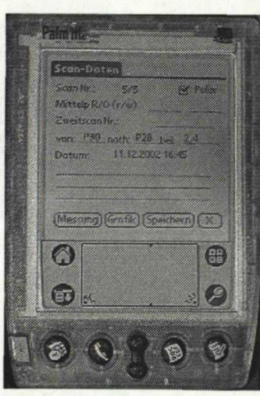

Figure 5 Palm input screen

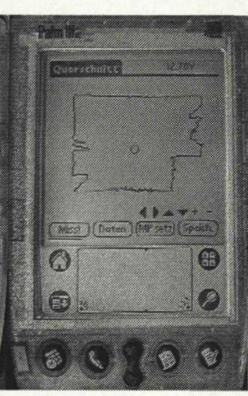

Figure 6 Palm control screen

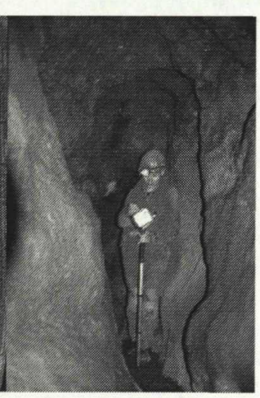

Figure 7 measurement in an ancient mine

After positioning the shapes in 3D space with Auto CAD, we export the complete data set to 3D Studio MAX. A mesh is constructed based on all the single shapes. Taking measurements e.g. every 30 cm provides the opportunity to built up a very detailed 3D model. This sounds very easy, but of course there are

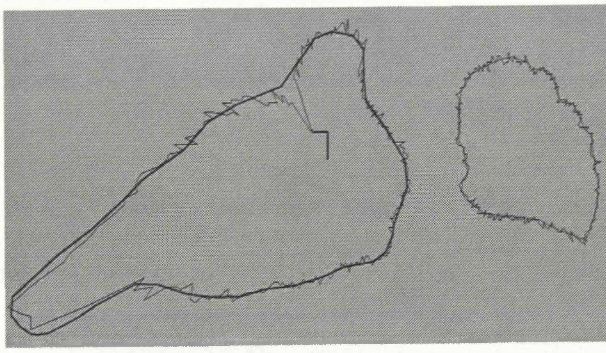

Figure 8 point reduction, smoothing and localisation of the tape

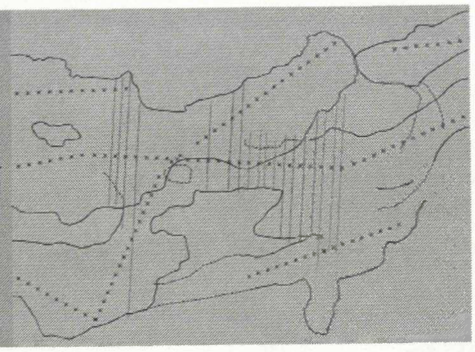

Figure 9 arranging the shapes with the help of a ground plan in AutoCAD

several "problems" which have to be solved during the construction:

WHERE IS THE RUB?

Especially in the area of conjunctions, not the complete cross section will be valid. Think (3 dimensionally!!!) of a Y-junction where the single incoming tubes are named A, B, C starting clockwise with the upper left one. Coming closer to the conjunction out of tube A, the laser will hit (on the left side) more and more parts of the B tube before A and B merge to tube C. Then you do the same with tube B (delete the parts witch hit tube A). This means that you have to delete those parts of a cross sections manually, which do not belong to the respective tube (gallery).

Now we have open cross sections and closed cross sections. If you come out of tube A or B, you first have to connect the closed cross sections with each other. In most cases there is no major problem of letting the computer do this automatically, but of course there are limitations of an automatism e.g. think of connecting two triangles, one of them upside dow .

There is at least one position in every tube where closed cross sections have to be connected with open ones (nearby the conjunction, remember that you opened them manually to get valid cross sections) Also the connection of two open cross sections can be difficult (e.g. two C-shaped sections one of them reverse). At the moment, those areas must be meshed manually because the computer can not decide automatically how to construct this.

Finally the meshed object is constructed, you can do "everything" you want to do with your 3D model. Adding textures and lights to the wire frame model, you can arrange an almost photo realistic 3D computer model. You can animate it (fly through the mine), or export it as e.g. VRML. Depending of the size of your model (and of course the capability of your computer), this gives you the possibility of walking through the mine in real-time and looking from any position, to everywhere you want.

FURTHER DEVELOPMENTS

At the moment we are thinking of different possibilities of capturing the position and orientation (6 degrees of freedom) of the profile-scanner as precise as possible (in relation to the local circumstances in a mine- dark, muddy, narrow). If the position (and orientation) of the scanner in relation to the tape is known (and digitally stored), it would be possible to arrange each single cross sections automatically in e.g. AutoCAD. There are many different trakking systems available, but for our field of application the inertial tracking system and the magnetic tracking system seem to be most suitable.

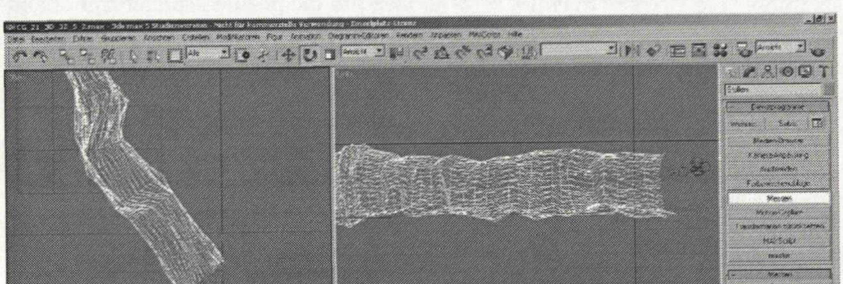

Figure 10 screenshot of a model of a mine in 3D Studio MAX

1 This optical light section device was developed and built in the Deutsches Bergbau-Museum in the early 80s.

2 Martin Melzer (Switzerland) from the HFG Karlsruhe did the programming of the Software for the Palm device and he developed the control unit. Martin Heller (Switzerland) has programmed the tool for converting the Palm -data to an AutoCAD readable dxf file.