Possibilities of 3-D visualisation of an "Erdstall"

A very narrow artificial cave from the Middle Ages

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Introduction

An “Erdstall” is an artificial cave. Numerous such caves have been built in the Middle Ages. The name "Erdstall" is not associated with "Stall" (= "stable"), but points to a spot (= Stelle). All of them have only one entrance and adit and winding tunnels are very narrow. Sometimes there is an extra narrow passage built in ("Schlupf") and in other sites small chambers are connected with the tunnel. Overall length is rarely more than 50m. They can be found in Ireland, Cornwall, some Scottish isles, the Bretagne and Central France, southern and central Germany, Upper and Lower Austria, Moravia, Slovakia, Hungary and Poland. Most probably there are multiple motives mixed together for now, as we can distinguish several types of ground plans, form and height of the tunnels, existence of chambers and other features. Such caverns were first investigated by the Catholic Austrian priest Lambert Karner, who in 1903 wrote a book about his results which is still a valuable source. In Lower Austria Edith Bednarik continued these efforts, which until now have not produced a valid explanation for the motivation for those people to undertake such exhausting work. So far discussed explanations include refuge or hiding places in warfare, caverns for souls to await doomsday, empty graves for ancestors not taken with them in time of colonisation, places to celebrate a cult or religion, hiding places for members of a forbidden sect, windstorm shelters (as predicted for doomsday to come) and others.

Site in Nonndorf near Raabs an der Thaya, northern Lower Austria

This tunnel was found when a 19th-century school building was adapted as modern residential building. When removing the floor layer a tunnel opened underneath. The owners immediately asked Edith Bednarik to investigate the discovery. They were so proud even to leave an entrance for future access, which will be situated in their prospective bathroom.

The tunnel is constantly sloping down to 6m below ground surface with an average height of 1,3m. After previous excavation it has an overall length of app. 13m. For the first 4m it is mined through gabbro, a very hard plutonic rock. At the contact zone with Paragneis there is a stone-built wall maybe closing a former branching. From there the tunnel follows this zone to a point where the material obviously was not stable enough for unsupported extension. From there to the end of the tunnel it has a stone-built vault. At the intentional lower end of the vault a boulder choke closes a further (formerly existing) extension. When found the vault had a hole in its top. From there and from the end loam with ceramics had filled the tunnel. Underneath the collapse the primary floor level is preserved with a dark loamy layer in it containing many pieces of charcoal. This helped dating the usage of the construction between 1407 and 1635 and extends underneath the collapse outside the end of the tunnel.

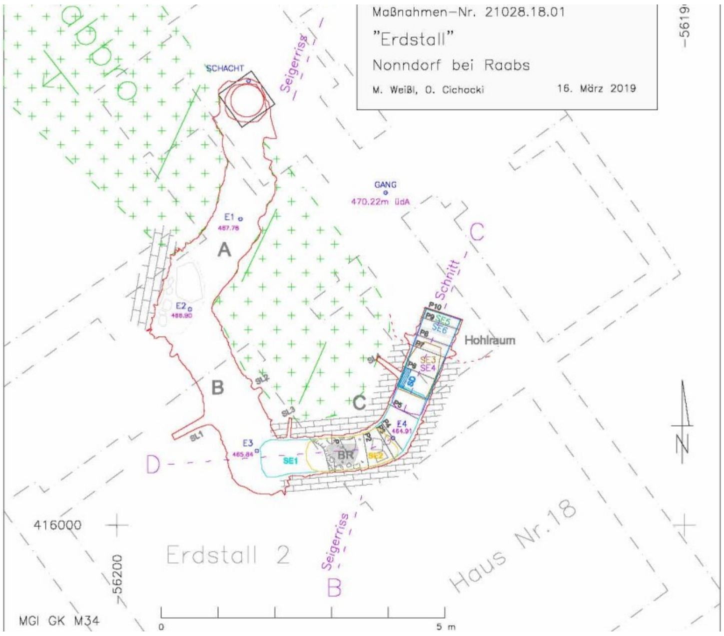

Fig. 1.: Ground view of the tunnel of Nonndorf, Lower Austria

A total station was used for marking fix points, for documentation of changes in direction of the tunnel and all other dimensions. Photographic documentation shows details and progress of the excavation.

For 3D visualisation, which was very challenging because of the narrow tunnel and the many details we cooperated with Fa. Riegl (laser scan visualisation) and LBI Wien (3D photo processing).

3D terrestrial laser scanning and automatic processes under difficult conditions

Since several years, terrestrial laser scanning has been used to measure above and underground structures. The demand for detailed digital 3D documentation requires suitable methods that allow the highest possible geometric resolution with the most efficient acquisition methods.

The latest developments of the terrestrial RIEGL VZ series scanners allows numerous high-resolution scans per hour and an automatic merging of point clouds, so called registration method, acquired from different scan positions even without GNSS information. Additional sensor information and a workflow matched to the respective project is required for such a registration.

For this laser scanning project a RIEGL VZ-400i scanner was used. Different sensors in addition to the laser scanning unit are on-board and will be used for highly precise automatic registration: a magnetic field compass, an IMU (Inertial Measuring Unit), a barometer, and an RTK (Real Time Kinematic) GNSS (Global Navigation Satellite System) receiver. Depending on the environment in which it is used, each individual sensor fulfils a specific task in the registration of scan positions.

A standard photo camera, calibrated to the laser scanner, can be mounted on top of the RIEGL VZ-400i. This makes it possible to add an additional RGB attribute to each point for visualization and interpretation. In respect to this project, the camera had to be dismounted due to the limited space available. Therefore no RGB information was recorded for the point-clouds of the “Erdstall” scans.

The challenge here was the very limited space in a GNSS denied area, indoor and underground. The scan project started outdoor with RTK position information. The GNSS information was used for georeferencing of the point clouds and for the automatic registration process. For further indoor and underground scans without GNSS connection the internal IMU information’s were important to record the trajectory from one scan position to the next and overlapping areas of the scan data for the orientation and fine adjustment were absolutely necessary. The final multi station adjustment, a calculation to minimize existing errors was done by RIEGL’s post processing software RiSCAN PRO. The implementation of external and independently surveyed control points is one of the most important steps to show the absolute and relative residuals of the project adjustment.

The result of all these steps in combination with an adapted workflow, describes a robust, a fast, detailed, and highly accurate measured scan project.

Fig.2. RIEGL VZ-400i

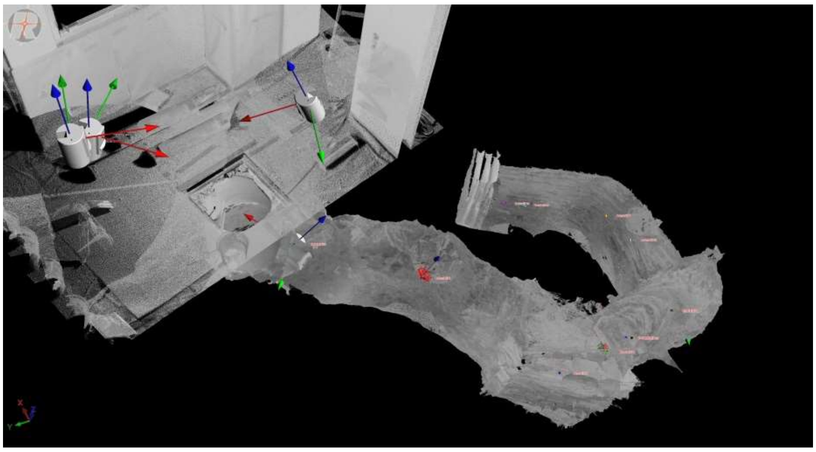

Fig. 3. Point cloud of the “Erdstall”, colorized by reflectance

Image Based Modelling (IBM) – an alternative method for the digital documentation of narrow spaces

Another way to digitally capture our world, called Image Based Modelling (IBM), uses digital photographs from which three-dimensional surfaces are computed. In this way, a 2½D point cloud can be obtained from multiple 2D digital photos, which not only contain the high-resolution surface but also its colour information.

The first calculation step is called Structure from Motion (SfM). SfM is often referred to as a synonym for the whole process. However, this step only calculates the position of the individual images in relation to each other and generates a coarse point cloud. Only in a further step, called Multi-View Stereo (MVS), the images are processed into a dense point cloud (Verhoeven 2016; Förstner & Wrobel 2016). These points can now be connected to form triangular surfaces on which the corresponding section of the photo texture can then be assigned.

Digitisation by means of IBM produces a high-resolution, photorealistic, three-dimensional image of the documented surface. However, it is obvious that this can only be as good as the quality of the underlying photos. Thus, already when taking the digital photos, great care has to be taken with their depth of field, exposure and colour authenticity.

For the documentation of narrow, long stretched and strongly angled rooms, as in the example shown here, additional challenges arise. Great attention must be paid to the choice of the photo position, their regular overlapping and homogeneous illumination, as only in this way the further applied calculation steps can automatically compute the photo position and create a realistic representation of the documented surface.

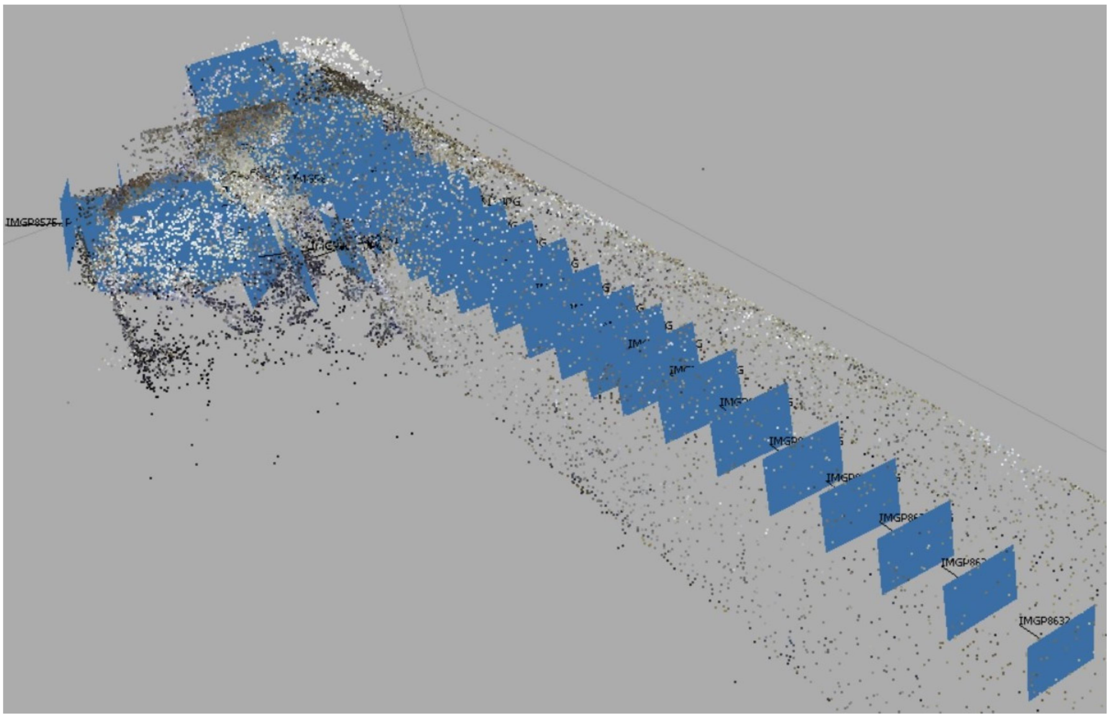

Fig. 4. Position of several photographs in a narrow gallery to reconstruct a 3D visualisation

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