Research overview

Recent developments in the laser scanning technology provide new tools and methods for a very accurate and cost-effective way of mapping complex volumetric landscape features such as caves. It is difficult to map such 3D features using traditional surveying methods without a large loss of detail. Also, the extreme environmental conditions in the cave (darkness, water, mud, or mist) make the mapping very challenging (Buchroithner, 2015). In this work, we have collected terrestrial laser scanning (TLS) data coupled with airborne laser scanning (ALS) data and orthomosaics to build a volumetric, 3D model of the Domica Cave and its surrounding area.

Study area

The Domica Cave originated in the largest karst region in the West Carpathians at the state border of Slovakia with Hungary. The total length of the cave system is around 3,400 m. However, it does continue into the Aggtelek karst region in Hungary. The cave was surveyed with a combined length of 26,065 m.

Terrestrial laser scanning

In addition to the TLS data, ALS data were acquired with a Sisib ALS40 scanner in collaboration with Phomapha s.r.o. in August 2014 during the last-on season. The achieved average point density on the ground is between 0.5 to 6 points per square meter depending on the land type (i.e., forested, grass, land, or sand). The accuracy of georeferenced point cloud is in the order of few centimeters. The TLS data were filtered and processed to derive a digital terrain model (DTM) and a digital surface model (DSM) in the area of the forms of regular raster grid (1 m cell size) with the LASSO software suite (Inmetry, 2014).

Airborne laser scanning

The TLS point cloud data were viewed and analyzed as cross-sections, 3D views and dynamic flythrough via the PARO Science and Bently-pointtools software. 3D cave surface model was generated from a decontaminated point cloud comprising only 0.5% of the original points (Galay et al., 2014). The model was generated as a triangular mesh in MeshLab (Cignoni & Ranzuglia, 2014) using the Poisson surface reconstruction method by Khedan et al. (2006).

The 3D model enabled volumetric calculations and parameterization of the cave surface properties. Mean curvature of the 3D cave surface model was calculated in MeshLab using the algorithms of Guardianes & Gross (2007) to parameterize convexity/concavity of the cave surface thus identify specific cave features such as stalactites, stalagmites and skylines (Galay et al., 2015).

The digital terrain model and 3D cave surface model were integrated in ArcGISGIS, which provided means for a complex perception of the cave system with the surface above it. Moreover, the integration enabled spatial analysis of the data in 3D as surfaces, not just the 3D points.

Combining the TLS and ALS data resulted in a 3D model of the area supplemented by other data representing several landscape components and factors potentially contributing to the development of the cave system (water flow routing, temperature, moisture in the cave). We have used several visualisation methods to represent the cave system which, if mutually combined, provide a better means of portraying the complexity of the karst landscape. By these means, we can better understand functioning of the cave system and dynamics of the spatial processes contributing to its development.

3D laser mapping and dynamic visualisation of the Domica cave, Slovakia

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References

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