Digital Photogrammetry in Microgravity Data Processing: a Case Study from St Catherine's Monastery, Slovakia

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Introduction

The use of the microgravity technique for cavity detection in the exploration of historical buildings requires the calculation of additional corrections that take into account the gravitational effects of surrounding man-made structures. The capability of digital photogrammetry to improve microgravity data processing was introduced in Panisova *et al.* (2012), where a new method for calculating building corrections based on photogrammetric reconstruction was used. The following case study demonstrates the application of this method with a microgravity survey undertaken at the Slovak archaeological site.

The St Catherine's monastery was founded in 1618 in an area where a 15th century Gothic chapel dedicated to St Catherine of Alexandria was situated. The original monastery church was rebuilt in 1646 to a larger Early Baroque edifice with dimensions of 52 x 13.5 m and with a 30 m high tower. The monastery complex was abolished by the order of the Emperor Joseph the Second in 1786. Nowadays, only the ruins of the church and the remains of the southern part of the monastery walls are preserved (Figure 1).

In the framework of the preservation project of the monastery ruins, complex historical, archaeological, anthropological and geophysical research has been conducted at the site since 1997. The main objective for geophysical survey carried out in the nave of the church was to detect and investigate features of archaeological interest (medieval crypts).

Figure 1: Aerial photograph of the St Catherine's monastery ruins. The inset shows a map of the location of the site.

Comparison of models

The convergent multi-station photogrammetric method was used for the digital spatial reconstruction of the church. The images were taken with calibrated digital cameras, the Olympus C-8080 and Nikon D-200. The photogrammetric processing was carried out using PhotoModeler software (Eos Systems, www.photomodeler.com). The reconstructed model of the church ruins (Figure 2B) comprises 4306 points and 8148 triangular facets. A total model accuracy of **0.018 m** (a spatial mean error) was achieved.

The traditional approach to the calculation of building correction is based on an approximation of the walls by a set of prisms (Figure 2A, Potent, Geophysical Software Solutions). The gravitational effect of the polyhedral model (Figure 2B) was calculated for an estimated density of 2.2 g/cm^3 in program Polygrav (Panisova *et al.*, 2012) based on the formula of Götze and Lahmeyer (1988). The differences between building corrections attain up to 45 µGals in the northern part of the map (Figure 3). These high values are caused by an inaccurate modelling of the tower in the Potent software. In general, it may influence the identification of probable subsurface features (in our case, crypt excavated in 2001).

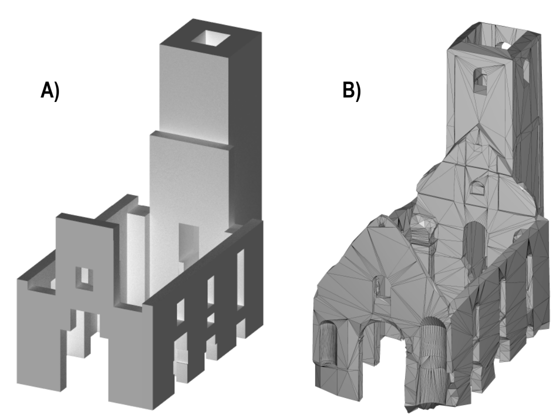


Figure 2: 3D models of the church approximated by a set of rectangular prisms – Potent software (**A**) and one polyhedron – PhotoModeler software (**B**).

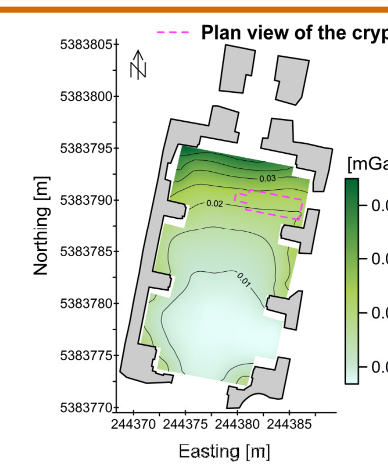


Figure 3: Difference map of building corrections (model **A** minus model **B**).

Geophysical survey

MICROGRAVITY

The nave of the church was surveyed on a closely spaced grid of 258 stations (point spacing of 1 m). A Scintrex CG-5 gravimeter was used to acquire the gravity data (mean error 4 µGal). Data processing included free-air, planar Bouguer, topographic (correction density of 2.4 g/cm^3) and building corrections. The harmonic inversion method (Pohánka, 2003) and Euler deconvolution (structural index one) were used for the estimation of the depth and size of anomalous sources.

GROUND-PENETRATING RADAR (GPR)

In order to eliminate the ambiguity inherent in microgravity method, the residual Bouguer anomaly map (Figure 4a) was overlapped and compared with GPR results from eastern part of the nave (Figure 4b). GPR measurements were taken using a GSSI SIR-20 system with a 400 MHz antenna. Thirty-six GPR profiles were acquired in zig-zag mode with 0.15 m line spacing. For time/depth conversion, the wave propagation velocity was estimated by diffraction hyperbola fitting with 0.09 m/ns. Processing steps for each profile consisted of t0-corrections, offset removal and direction ordering.

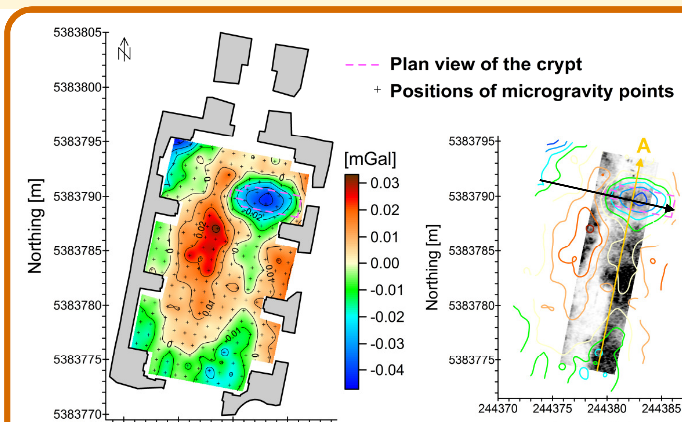
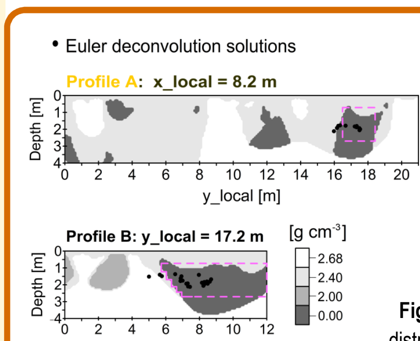


Figure 4: (**a**) The residual Bouguer anomaly map, with regional trend removed. (**b**) GPR horizontal time slice stack between 20–40 ns (approx. 0.9–1.8 m depth).



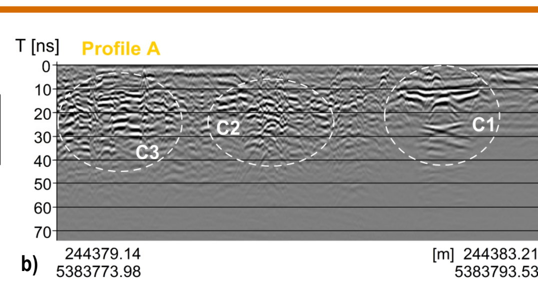


Figure 5: (**a**) The interpretation of microgravity results: the density distributions in two vertical sections for Profiles A and B. (**b**) The GPR vertical time section (Profile A in Figure 4b) running in SW-NE direction.

In Figure 4b, two distinctive reflection anomalies indicate the existence of two features. The top of the known air-filled crypt (C1, Figure 5b) is indicated by a strong, almost horizontal reflection. The chaotic reflection patterns of features C2 and C3 (Figure 5b) suggest that the expected crypts are destroyed and filled by debris. The depth to the top of these features is estimated to be around 0.5 m.

The vertical density section (Profile A, Figure 5a) can be correlated with features seen on the GPR vertical section (Figure 5b). For the air-filled crypt, the dimensions (5 x 1.9 x 2 m) and position (its top is situated in a depth of 0.6–0.8 m below the ground) have been confirmed by both method. The other two features (could be partially filled) most likely relate to two crypts documented in historical archives. They are planned to be excavated in 2013.

Conclusions

- **We have shown that the digital models of the historical buildings created from photographs with a special photogrammetric software can be directly utilized for the calculation of their gravitational effects in microgravity technique. A novel approach of microgravity data processing, which is designed particularly for archaeological applications, provides for high accuracy of calculated building corrections.**
- **This case study illustrates the advantage of combining geophysical methods that are based on different physical parameters. The combination of microgravity and GPR surveys has proved to be a very effective and non-destructive tool for archaeological research.**

References

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