World War 2 bombing relicts identification using lidar-derived precise digital terrain model

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Abstract

At the end of World War 2, large industrial areas supporting the German army bombed by the allied forces. Several thousands of bombs were used within Czechia, leaving identifiable bombing craters until the present. The areas subjected to bombing may still contain unexploded bombs because a minor portion of the bombs used did not explode. These areas are mainly close to the former industrial sites, and with the current trend of city enlargements (new residential areas and industrial parks), we may face the risk of finding unexploded bombs in the new construction sites. Identification of bombing relicts (craters) is thus a way how to prevent such accidents. Different types of remotely sensed spatial data might be used for such identification. The historical data sources are preserving the state right after the bombing events – in this paper; we work with aerial images from 1946. The other data source suitable for the identification of such relicts is the LIDAR. Within this paper, we present the usage and comparison of the "Digital Terrain Model of the Czech Republic of the 5th generation" available for the whole Czechia and our LIDAR field survey with UAV based LIDAR. Several methods of pixel- and object-based image classification were tested for automatic identification of the bombing residuals.

Keywords: crater identification, military landscape, aerial imagery, LIDAR.

INTRODUCTION

The area of the North-West Bohemia was at the end of World War 2 bombed in the industrial regions – i. e. the Sudetenländische Treibstoffwerke (Chemical Factory) in-between the towns Most and Litvínov or the railway crossing in Ústí nad Labem. Within the proposed paper we focus on the region of the STW. More than 15 000 bombs were used by the allied forces. With respect to the large landscape changes in this region (heavy industry, open-pit mining) most of the bombing relicts vanished. With the use of the "Digital Terrain Model of the Czech Republic of the 5th generation" (CUZK, 2020). There were identified several bombing relicts in the northeast area of the former Chemical Factory (see **Fig. *1***, Sampling Plot A and B).

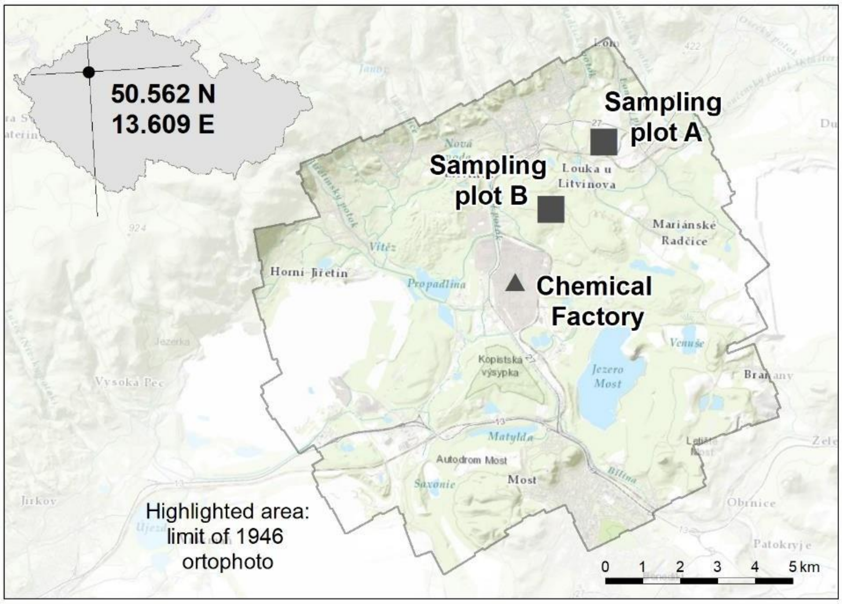

Fig. 1 Area of interest

DATA AND METHODS

The identification of the craters is possible using different data sources. After each bombing event (May 1944 – March 1945), an "in-situ preliminary survey" was performed. This preliminary survey was carried out by visual identification and subsequent entry into the cadastral map (position of the craters were marked for evidence of damage and general reporting purposes). The more accurate available data sources used for identification are the contemporary aerial images (Stichelbaut et al., 2016; Capps Tunwell, Passmore & Harrison, 2016). The first postwar aerial survey was performed in 1946 and the raw data were thus obtained from the Czech office for surveying and cadaster. The archival aerial images were processed using the standard ways of photogrammetry. The resulting orthophoto was used for craters identification together with the cadastral map reports with marked craters and manually digitized into compact GIS layer (see **Fig. 2**). The Sampling plot A and B with persistent craters were later found in areas untouched by open cast mining activities by comparison of current and afterwar soil and geological maps.

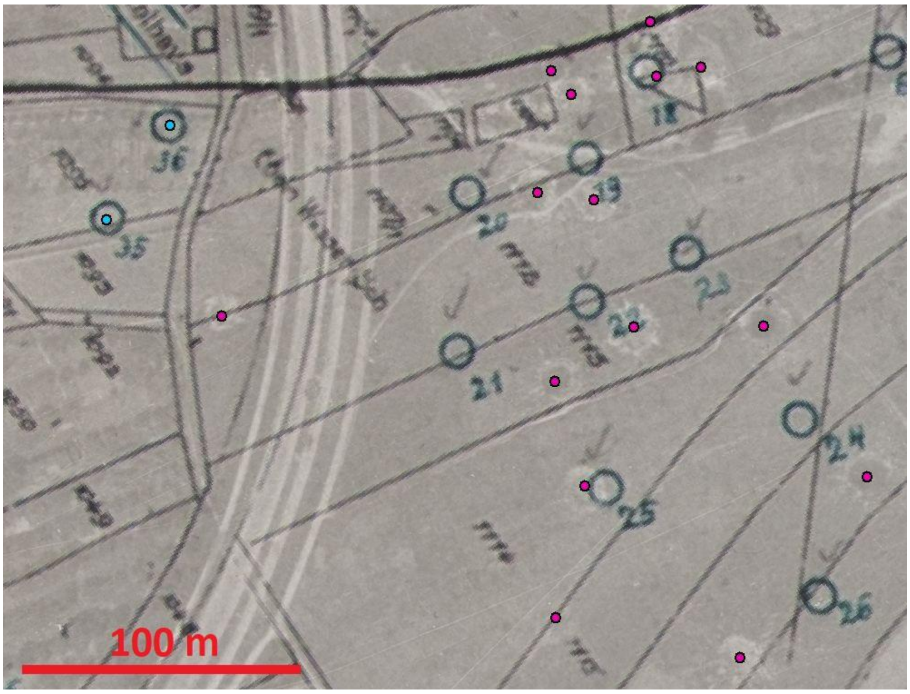

Fig. 2 Crater positions as visually identified after the bombing event into a cadastral map and craters (center points) as identified on corresponding processed archival aerial images

The current orthophoto of the bombed sites is hard to use for the bombing relicts identification as the areas (if still exist) are overgrown with vegetation. The LIDAR technology is thus suitable for this purpose as the LIDAR pulses penetrate the vegetation. The initial identification was performed based on the "Digital Terrain Model of the Czech Republic of the 5th generation" (DMR 5G) data – the publicly available DMR 5G data are filtered to 1 point per m^2. The filters applied on the RAW LIDAR data and the subsequent spatial resolution (1 meter) may hide some of the bombing relicts. The UAV based LIDAR scener Riegl VUX1-LR was used for our LIDAR survey. This scanner is primarily dedicated to be used on UAVs but with respect to legislation (UAV flight over inhabited areas), in this case, the LIDAR scanner was mounted on a small aircraft. The scanning altitude was 300m and the resulting point density is approximately 25 points per m^2. The resulted DEMs based on the DMR 5G and our LIDAR survey are presented in **Fig. 3**.

Fig. 3 Craters identified on our LIDAR survey (right) and the same areas identified on the „Digital Terrain Model of the Czech Republic of the 5th generation" LIDAR data available for the whole Czechia.

The analysis of gathered data was followed by crater localization/identification. The crater identification research is well established in planetary science. Here, the knowledge of population and spatial distribution of the craters (Moon, Mars) facilitate the further study of stratigraphy and geology of the planetary surfaces (Lee, 2019). The identification itself could be done in several ways ranging from manual to fully automatic classification process. Firstly, the initial step in our case was done by visual interpretation, where enhancement of the terrain morphology as proposed by Davis (2012) was done (**Fig. 3** right). Such initial step is later used for localization of the training samples. Secondly, our aim is to test different approaches in order to find the best solution among pixel- and object-based image classification for automatic identification of the bombing residuals. As concerning the selection of particular methods, we have decided to test and compare (i) object – based classification methods (for extraterrestrial application see Vamshi et al., 2016, for terrestrial application see Magnini et al., 2017) and (ii) pixel based methods based on Convolutional Neural Networks (CNN) classification (see also Cohen et al., 2016; Benedix et al., 2018) with successful testing on terrestrial environment (Brenner et al., 2018). Our preliminary results (**Fig. 4**) shows moderate success in crater identification via CNN algorithms (Klear, 2018) due to different (i) resolution of source imagery, (ii) size of the craters (our object are usually 5 - 10x smaller) and (iii) roughness of surface (cf. clean moon surface vs. variable surface in detailed DEM on **Fig. 3**).

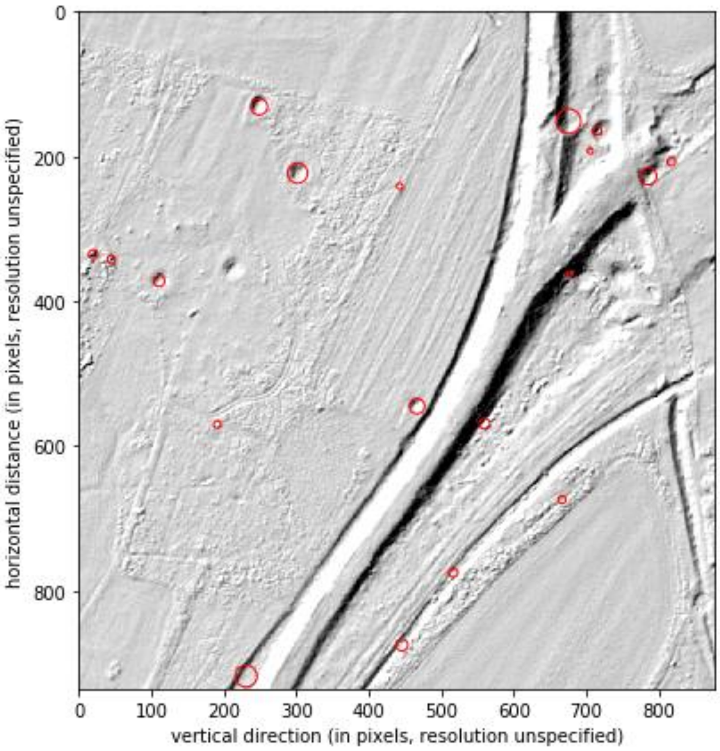

Fig. 4 Craters identified by PyCDA (Klear, 2018) algorithm (marked as red circle).

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