Geospatial analysis of the conflict landscape for supporting Non-Technical Survey

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Abstract

In this paper, we explore the potential of geospatial analysis for supporting Non-Technical Survey. Several datasets are used for reconstructing the historical conflict landscape that forms the context of ERW contamination. This analysis aims at verifying and refining units' positions derived from military archives, for then inferring the location of mine obstacles based on contextual information and expert knowledge. Preliminary results indicate that the method offers interesting perspectives and that it should be refined by integrating additional datasets, processing and expert knowledge.

Introduction

The analysis of digital geo-information in Geographic Information Systems can support Mine Action at different stages. The GICHD, with the University of Geneva, has produced an issue brief on the topic (Lacroix et al., 2013). The possibilities range from simple overlays of geographic layers to complex geospatial analysis combining various datasets for modelling and mapping, e.g., the ERW contamination density, the potential displacements of mines caused by water runoff, the populations most exposed to the risk, the accessibility of an area, etc. The output of such analyses can be used in the survey process, in the priority-setting phase and for planning and reporting operations.

Our purpose here is the application of geospatial analysis to the reconstruction of the historical conflict landscape that forms the context of ERW contamination, in support to the Non-Technical Survey. The research is being carried out in the framework of the project TIRAMISU, for the development of a tool called T-SHA. This potential application seems to have been little explored up to now in Mine Action. Beside, in the field of conflict archaeology, literature on the use of geospatial information for the reconstruction of ancient battlefields mainly reports the implementation of feature extraction from aerial photos or satellite images (Kaimaris, 2011; Passmore et al., 2013), sometimes in combination with simple GIS functions (Nolan, 2009).

In a book published recently (Matić et al., 2014), CROMAC-CTDT authors highlight the elements that should be taken into account when carrying out a military-oriented interpretation of a Suspected Hazardous Area. They underline the fact that information extracted from available military archives should be completed with other elements such as topography, hydrography, communication networks (e.g. roads and tracks), vegetation, soil properties and land use. In this paper, we explore the potential of remote sensing and GIS for supporting the work of the expert in this perspective.

Study area

The Region of Interest (ROI) that was selected for developing the method is located in the Dinaric Alps, in Croatia. It is a mountainous zone characterised by irregular karst topography. The terrain is rugged and rocky and it displays little trace of human activity, beside ancient dry stone walls enclosing grassy areas used for grazing (typically in sinkholes), and dilapidated shepherd's huts. Mine laying took place in the early 1990s, during the Croatian War of Independence. Two decades after the end of the conflict, traces of military activity have become difficult to pinpoint. Fortifications were erected using mainly natural materials present in the environment, or they were covered with stones to remain inconspicuous, and earthwork-digging possibilities were limited due to the nature of the soil. The constructions are generally small and have been damaged by time and weather events, making them sometimes hard to spot, even in the field.

Data

Expert analysis of military archives by CROMAC surveyors resulted in the production of layers of polylines (vectors) representing the positions of units of both warring parties that were active in the area. These polylines have a set of attributes characterizing notably the reliability of the source and the date of occupation of the positions. Since, in a first stage, no piece of information should be discarded, the polylines were provided to us unfiltered (one polyline per source and per position), which means that a single unit position at

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a given time is likely to be represented by several polylines. Positions where fortifications were erected were also derived from archives and provided as layers of points. Surveyors also provided a list of places where they expect that additional information can be extracted thanks to earth observation.

Topographic maps on the scale 1:25000 and 1:5000 are available from the WMS of the Croatian Geodetic Institute.

The remote sensing data used in the study are:
(i) 3K colour aerial photographs (RGB) shot during a flight operated by DLR in autumn 2013 (Kurz et al., 2012). They were radiometrically calibrated, atmospherically corrected, orthorectified and mosaicked by DLR. The final product has a spatial resolution of 15cm
(ii) a raster Digital Surface Model (DSM) that has a spatial resolution of 30cm. It was generated by DLR using the 3K data. A DSM is an elevation model that includes the objects present on the terrain (vegetation and man-made features such as buildings).
(iii) WorldView-2 satellite images shot in April 2013. These images have a panchromatic band and eight multispectral bands; their spatial resolution is 50cm after pre-processing and pansharpening.

Data collected in the field during a survey carried out under guidance from a surveyor were also used in the analysis.

Methods and preliminary results

1. Feature extraction

Referring to the recommendations made by CROMAC-CTDT experts, features that are relevant for the analysis are being extracted from earth observation data:

- Sections of the tracks present in the area and that are not included in the topographic maps could be extracted automatically from WorldView-2 data by adapting a line detection algorithm initially developed for the extraction of trenches (Lacroix and Vanhuysse, 2014). Since these tracks hardly stand out from their background, the extraction had to be completed by Computer-Assisted Photo Interpretation (CAPI).
- The semi-automatic extraction of forests is ongoing, using all available remote sensing sources. Ideally, historical images should be used since the forest edges do not remain stable in time if they are not maintained.
- Some of the features that could have influenced the operations are absent from the area, i.e. mainly watercourses and water bodies.
- Feature relating to the land use that could be a consequence of mine laying are also absent, e.g. abandoned/used cultivated land.
- Features that indicate military activity and that can be considered as Indicators of Mine Presence (IMPs), e.g. bunkers, shelters, linear fortifications, etc., are small and unlikely to be extracted using (semi-)automated methods. To avoid the tedious process of screening the whole area visually and to increase the chances of finding IMPs, the photointerpreter's understanding of the conflict landscape can be leveraged by geospatial analysis so that CAPI can be intensified in places where IMPs are most likely situated. The identification of favourable locations is explained in the next section.

2. Geospatial analysis

The requirement expressed by CROMAC surveyors is that units' positions derived from archives are verified and refined so that mine contamination can then be inferred using contextual information and expert knowledge.

Polygons representing the areas to investigate more closely were digitized based on the list of places provided by surveyors and topographic maps.

The Digital Surface Model was resampled to a resolution of 9m. It was used for computing a Topographic Position Index (TPI) in a neighbourhood of 500m. The Topographic Position Index compares the elevation of each cell in the DSM to the mean elevation of a specified neighbourhood around that cell (Weiss, 2001). Positive values indicate areas that are higher than their surrounding, whether negative values indicate areas lower than their surroundings. An image of slope was also computed using the DSM. The TPI was classified into four classes, taking into account relative elevation compared to the surroundings (lower, about the same elevation, higher, much higher). The slopes were classified into five classes. The combination of classified TPI and slope values allowed the identification of landforms that are favourable for positioning units for observation or firing purposes, i.e. areas that are quite flat and higher or much higher than their surroundings. This was verified by overlaying the points representing expected locations of fortifications derived from archives and observations made in the field on the map of landforms. CAPI was then performed, focussing on these favourable locations, for finding traces of military activity that can be considered as IMPs. Several fortifications (mainly shelters) could be extracted; the result will be submitted to an expert for validation.

The next steps were developed using one of the units' positions that were identified. Virtual observers were positioned in places where fortifications were located, and their field of view in the direction of the other warring party was computed using a directional viewshed algorithm. The combination of this new layer with the layer of landforms allowed us to refine the search for other candidate units' positions. A rest camp (confirmed by field observations) could notably be identified just outside the limit of the viewshed.

Areas that are quite flat and that are also lower or much lower than their surroundings are not favourable for observation or firing, but rather for military logistics installations, provided that they are not visible for observers from the other side and that their accessibility is reasonably good. Some candidate IMPs could be located by examining the landforms, the field of view and a track extracted from satellite imagery.

Once units' positions have been located, potential mine contamination "hotspots" can be identified. This involves military knowledge relating to mine laying and to the temporal dynamics of the conflict, but also fine-scale topographic analysis, information on the land cover/land use, trafficability analysis, etc. A first rough hotspot was mapped using a directional buffer algorithm. It should be refined thanks to interaction with experts.

Future developments

The preliminary results will be cross-checked thanks to interaction with surveyors. Results will then be refined thanks to the integration of additional data (e.g. a map of forests), processing (e.g. trafficability analysis, fine-scale topographic analysis) and expert knowledge (e.g. distance between fortification and mine obstacles, temporal dynamics of the conflict).

Conclusion

Geospatial analysis of the conflict landscape offers interesting perspectives for supporting Non-Technical Survey. It allows leveraging the analytical capabilities of the expert, who should remain the lynchpin of the interpretation of a Suspected Hazardous Area. In a mountainous environment, terrain plays a major part in the analysis even in modern warfare, as combatants are likely to seek natural cover and dominant positions. The applicability of the method to other types of environments should be assessed and the necessary adaptations should be considered. The method is not applicable to contexts where mine laying was not planned according to a strategy. In Cambodia for instance, many nuisance mines were laid, resulting in an unstructured spread of mines in large suspected areas.

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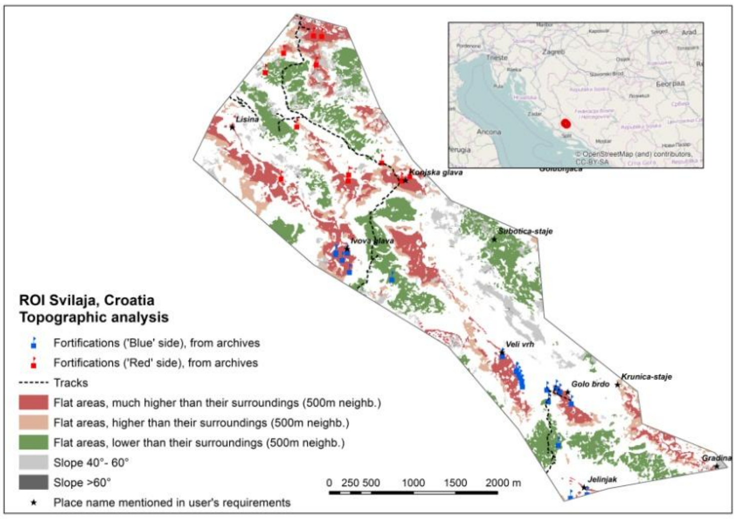

Figure 1: Fortifications mapped from archives confirm that a number of flat dominant areas identified by semi-automated topographic analysis (in light and dark brown) have been occupied by combatants. Other fortifications are located on lower ground, in the vicinity of the track extracted by CAPI.

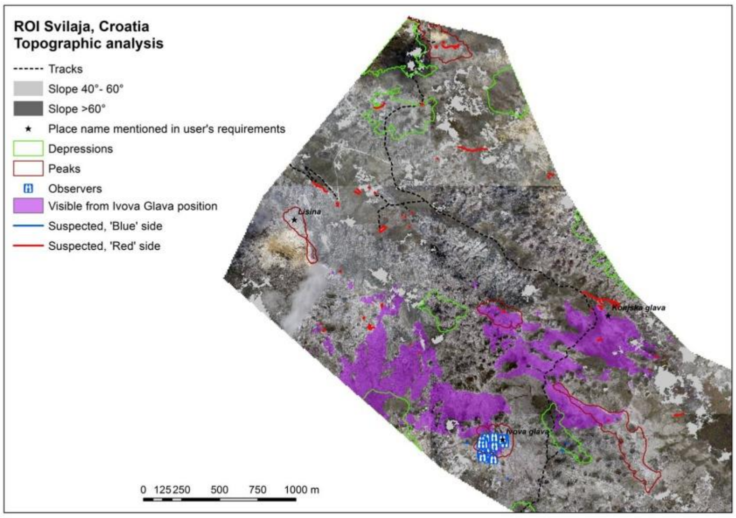

Figure 2: The field of view of virtual observers placed on one of the unit position is shown in purple. Certain positions of the other warring party can be found just beyond its limit. The base layer is 3K aerial photographs**.**

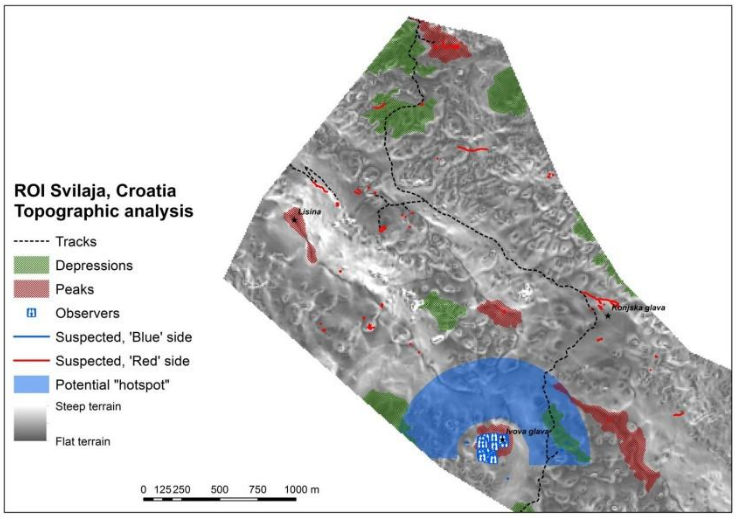

Figure 3: Once units' positions have been found, 'hotspots' of contamination can be delineated. Here, a rough delineation (in blue), to be refined thanks to additional datasets and processing, and also expert knowledge. The background is a slope image.