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The Cultural Landscapes Scanner (CLS) project

Earth Observation and automated detection of subsoil undiscovered cultural heritage sites via AI approaches

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THE PROJECT

The Europeans Space Agency (ESA)-funded project Cultural Landscapes Scanner (CLS) aims at investigating and developing Artificial Intelligence methods — and related Machine Learning (ML) and Deep Learning (DL) solutions — for the automated identification of subsoil, yet undiscovered cultural heritage sites on

- satellite-based multispectral Earth Observation (EO) data
- airborne LiDAR data.

Detection of underground archaeological deposits is based on the recognition of anomalies or traces on bare soils, crops or vegetation that are determined by the presence of archaeological structures under them. Automating remote sensing analytics via AI produces large benefits in terms of cultural heritage — and especially archaeological— object detection in satellite imagery and represents a significant breakthrough in the discipline as it allows to replace existing procedures based on subjective observation. CLS works also toward improving existing approaches to the identification of ancient land division systems —and more generally of landscape patterning— by automating procedures of similarly-oriented linear feature detection.

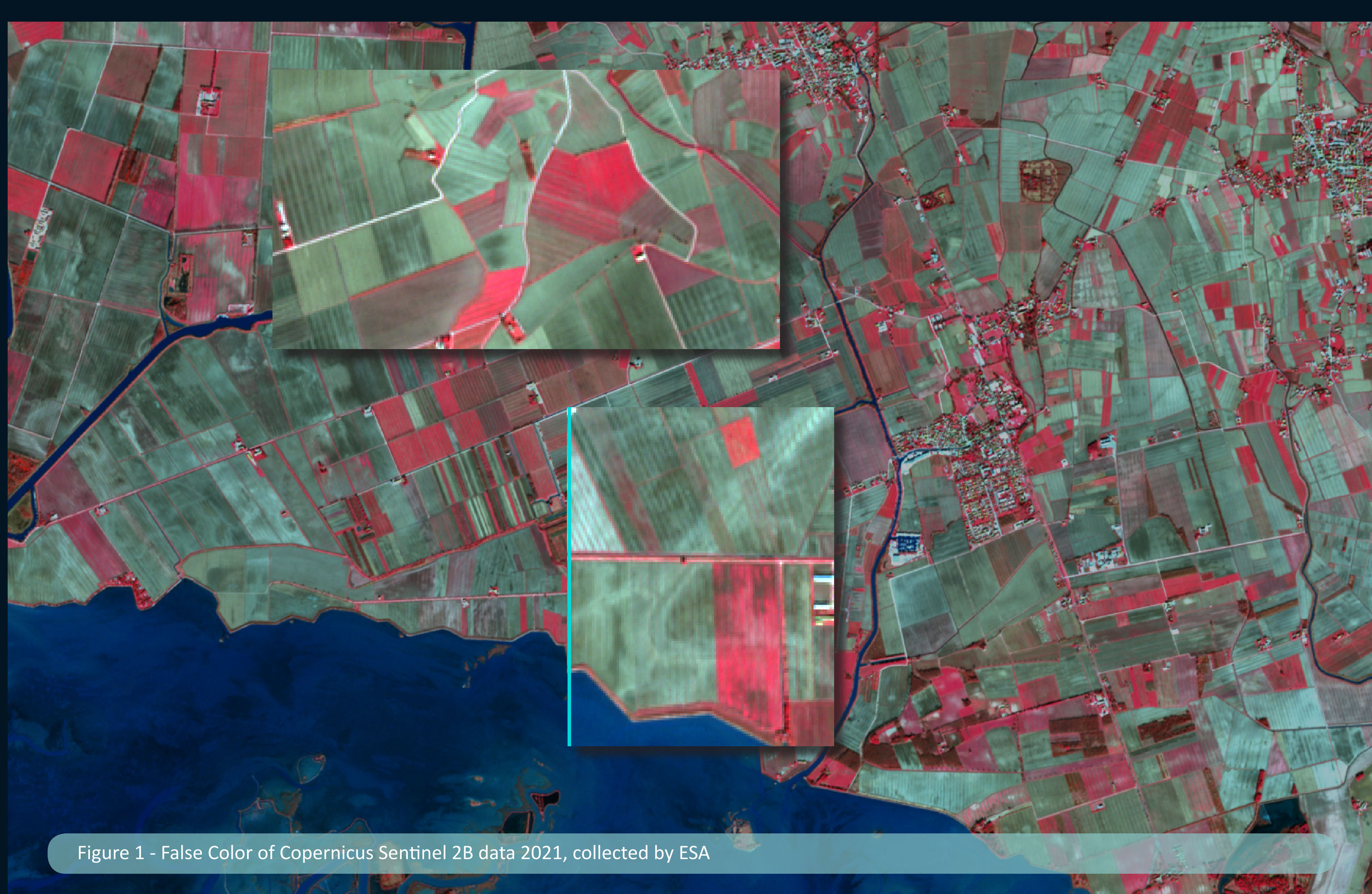

Figure 1 - False Color of Copernicus Sentinel 2B data 2021, collected by ESA

THE CHALLENGES

- Scarcity of robust AI-based tools leveraging the current abundance of EO data through appropriate automatic processing pipelines.
- Shortage of custom designed DL architectures for the detection of specific cultural heritage objects and patterns related to anthropogenic interference on landscapes in the past.
- Lack of a standard set of performance evaluation methods that better resemble the archaeological assessment process of ML-based detections and, additionally, ease objective cross-study comparisons.
- Deficiency of publicly available quality datasets suitable for ML model training and / or testing related to a variety of archaeological features.

METHODOLOGY

CLS aims at setting a benchmark in the use of RS data for the automatic identification of various classes of undiscovered archaeological sites through the integration of cutting-edge AI techniques with archaeological research and fieldwork.

AI FOR ARCHAEOLOGICAL SITE DETECTION

The project encompasses the exploration of state-of-the art object detection models properly trained to identify and locate instances of cultural heritage objects. Different Faster R-CNN network implementations are employed, with specific architecture variations (e.g., in the backbone CNN, or feature extraction layers, or training regime parameters). All models have pre-trained weights subsequently fine-tuned on a LiDAR dataset, properly data-augmented through image resizing and flipping.

The figure 2 shows the predicted bounding boxes generated by one of these models. A confidence score is calculated alongside with each bounding box, representing the estimated probability in percentage of the prediction correctness. The color of the box itself is assigned based on this score.

Another objective of the CLS project is the design of novel "finer-grained" detection approaches belonging to the semantic segmentation networks class, in order to automatically recognise specific regions of an image related to undiscovered cultural heritage objects, with particular focus on semi-supervised architectures that require only few labelled remote sensing data for the training process. The semantic segmentation outcomes is being checked from an archaeological perspective to establish how the granularity of the detection can impact the quality of the prediction.

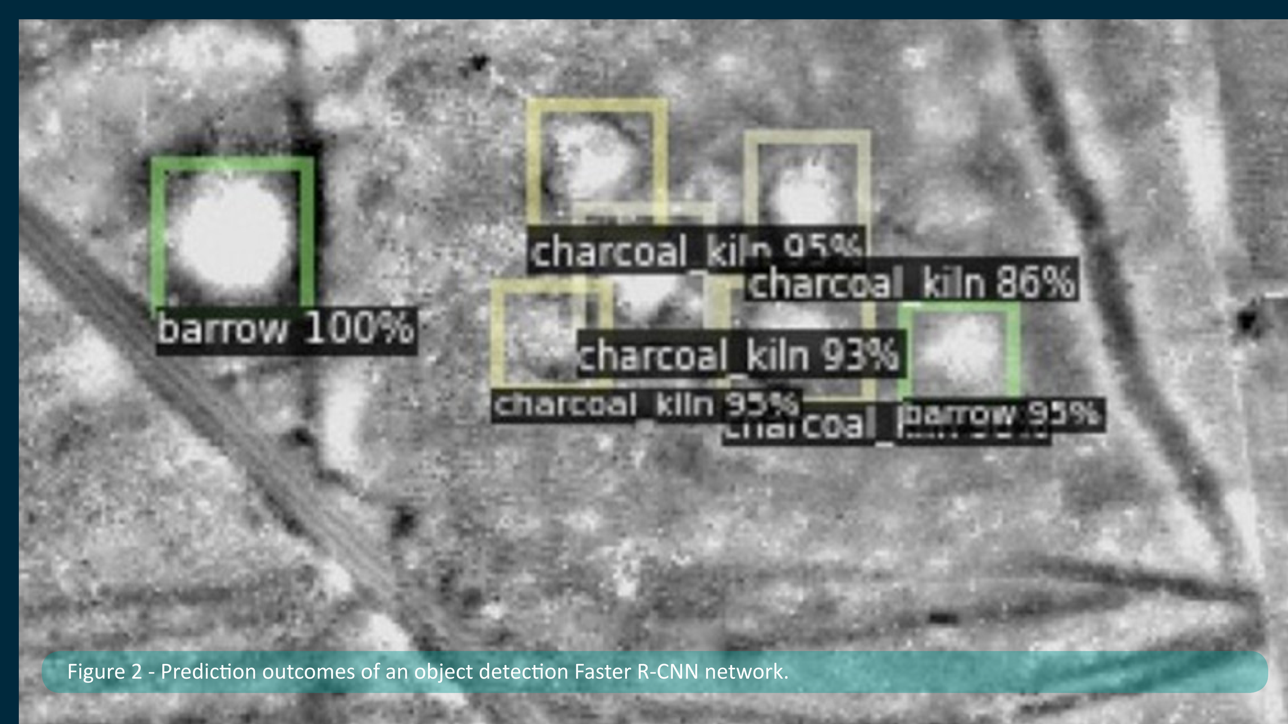

Figure 2 - Prediction outcomes of an object detection Faster R-CNN network.

NOVEL OBJECT DETECTION EVALUATION MEASURES

Unlike most general ML solutions in computer vision, archaeological research relies heavily on geospatial information when considering the predicted outcomes of a model, depending on the shapes or areas containing archaeological objects.

While for "discrete archaeological objects" (e.g., items with a compact, convex and localised shapes) the position of the central coordinate is more informative than their extent, for "landscape patterns" (e.g. large-scale non-localised shapes, like adjoint roughly rectangular embanked plots relative to ancient parceling system) the extent and coverage represents a more relevant information on - for instance - yield and demographics.

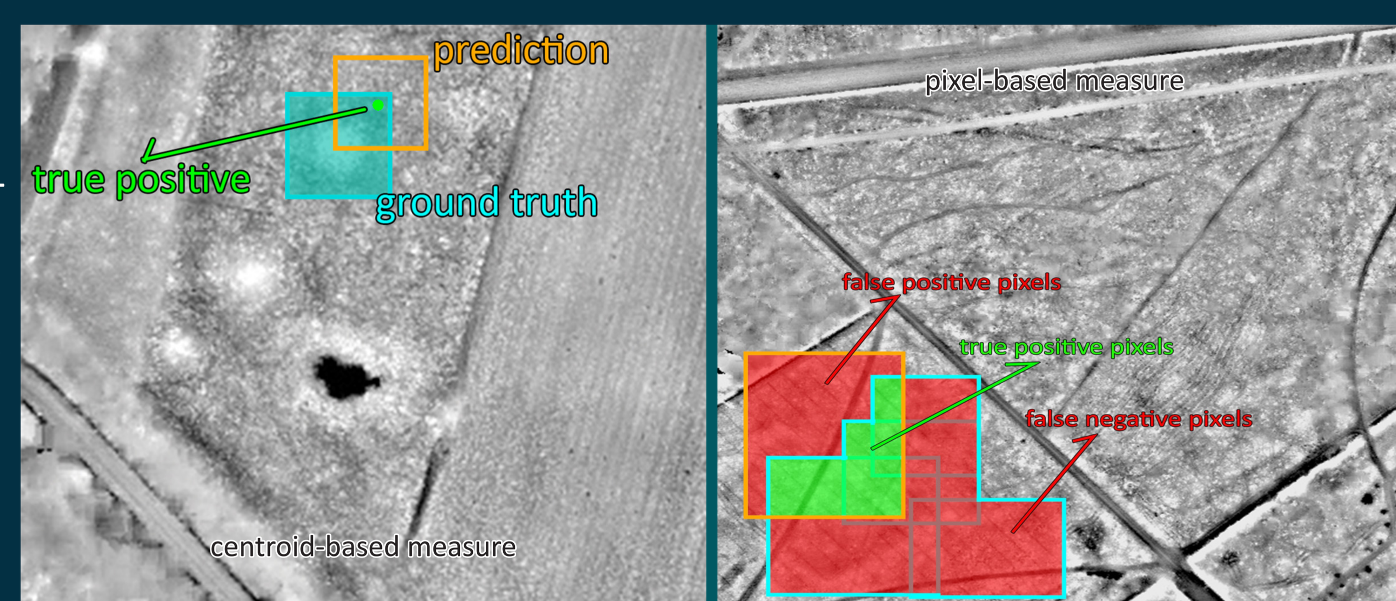

Figure 3 - (Left) The centroid-based measure provides a quantitative evaluation of the spatial relationship between predicted and ground truth objects. (Right) The pixel-based measure provides a quantitative evaluation of the coverage of the ground truth bounding boxes with the predicted ones

CLS tackles the shortcoming of archaeology-oriented automatic evaluation measures for model prediction's assessment by introducing and implementing two novel algorithms, namely 'centroid-based' and 'pixel-based'. While the former better approaches discrete objects, where location is more informative than extent, the latter relates to landscape patterns, considering both the position and the coverage of predicted areas.

In the centroid-based, a prediction bounding box (in orange) is considered as a True Positive (TP) if its centroid falls inside the area of (at least) one ground truth's bounding box (in light blue). In the pixel-based each pixel of a predicted bounding box (in orange) is considered as a TP (in green) if it belongs to one of the ground-truth bounding boxes (in light blue); otherwise, it is considered as False Positive (in red). The pixels of each ground truth bounding boxes that are not covered by any predicted bounding box are considered as False Negative (in dark red).

CREATION OF A PUBLICLY AVAILABLE DATASET

The project will further encourage the collaboration between cultural heritage and AI scholars releasing the first publicly available multi-modal dataset containing both Sentinel 2 multi-spectral images and LiDAR data of the archaeological landscape of Aquileia (Italy), a major city of the Roman Empire. To support and promote the dissemination and subsequent usage of this novel digital asset, proper metadata information will be provided as well.

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