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Aerial point cloud classification in archaeological scenarios

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Abstract

LiDAR point clouds are becoming more and more used and important in archaeology for revealing ancient structures hidden below canopy. The tutorial will present how 3D semantic segmentation in aerial archaeological point clouds could support the identification of hidden structures and the interpretation of heritage scenarios.

1. Introduction

The use of Airborne Laser Scanning (ALS) and Light Detection And Ranging (LiDAR) technologies has proven to be essential for detecting and mapping archaeological evidence at a large scale [OPI16; CAM17; GHML18]. In case of dense forest or shrub-covered contexts, ALS is necessary, allowing for the detection and mapping of archaeological evidence below the canopy, thanks to LiDAR sensors' capability to penetrate the vegetation and the possibility to filter out the vegetation signal from the acquired data. Recently, the concept of Digital Features Model (DFM), a variation of the Digital terrain Model (DTM) that combines ground with above-ground archaeological structures in a comprehensive model meant to be used for archaeological analyses and interpretations, has been utilized in numerous publications [PCF15, ŠLE21, MGC*22, DBV22, FON24], however for its generation it is necessary to map the ground and the archaeological evidence on the raw data, to then separate them from the vegetation. This task requires extensive, time-consuming manual work, making the use of an automated procedure indispensable. Recent works [MGC*22, CMR*25] employing machine learning based pipelines to generate DFMs have proven to be successful in mapping both archaeological elements above ground and even at ground level (i.e., low-standing walls covered by vegetation).
This tutorial's primary objective is to illustrate how to automate the generation of a high-quality DFM of large and densely vegetated areas, leveraging the potential of Artificial Intelligence methods to speed up the procedure. To this aim, we provide a brief walk-through of one of Machine and Deep Learning based pipelines to perform the semantic segmentation of archaeological datasets acquired with airborne- or drone-based LiDAR sensors and create a DFM.
The tutorial is subdivided into theoretical sessions as well as hands-on applications on real case scenarios. In total, the tutorial is subdivided into four main sessions:

- **3D semantic segmentation**: a brief introduction about 3D semantic segmentation and its general purpose in point cloud processing (30 min);
- **3D semantic segmentation for archaeology**: an explanation of the 3D semantic segmentation importance in the wider context of archaeology, and especially for landscape archaeology (30 min);
- **Real Life applications (case studies)**: some real-life case studies where semantic segmentation was successfully applied to generate DFMs (1 hour);
- **3D semantic segmentation for archaeology (hands-on)**: a hands-on session where the participants can learn how to go through the entire pipeline and successfully generate a DFM (2 hours).

2. Tutorial key aspects

2.1. 3D Semantic Segmentation

Tutor(s): Fabio Remondino, FBK Trento, Italy;
Contents: the wider concepts of Machine/Deep Learning methods for semantic segmentation of 3D data. Key concepts and terminology will be explained (classes, features, training, generalization, metrics, etc.) in order to provide the participants with the necessary knowledge to understand and perform the hands-on part of the tutorial. Potentialities, limitations and purposes of using a Machine/Deep Learning approaches to perform the semantic enrichment task will be also presented.

2.2. 3D Semantic Segmentation for Archaeology

Tutor(s): Stefano Campana, University of Siena, Italy;

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Contents: excursus on the use of ALS in the Landscape Archaeology, the challenges that still need to be addressed, as well as the advancements and successes made over the years in identifying and mapping archaeological features normally hidden under canopy. Needs for high-resolution and accurate DFMs to detect archaeological features hidden under the canopy will also be presented.

2.3. Real-life application (case studies)

Tutor(s): Gabriele Mazzacca, FBK Trento, Italy and Prospero Cirigliano, IMT Lucca, Italy;
Contents: real-life scenarios where machine/deep learning pipelines successfully segmented the datasets allowing to retrieve hidden structures will be presented. Results will focus on complex scenarios characterized by dense forest and shrub cover, typical of the Mediterranean area. Successes and limitations of the procedure will be highlighted through qualitative and quantitative approaches. The visual analysis and interpretation of the generated DFMs will be also presented.

2.4. 3D Semantic segmentation for archeological airborne point clouds (Hands-on)

Tutor(s): Gabriele Mazzacca, FBK Trento, Italy and Prospero Cirigliano, IMT Lucca, Italy;
Contents: the last session will be completely dedicated to a hands-on application of a machine learning pipeline for processing Archaeological ALS 3D data. Tutors will drive the participants through the entire pipeline, from the data preparation phase (manual annotation, feature extraction, etc.) through the training and inference steps, till the quantitative evaluation and to final DFM generation and visualization for archaeological interpretation.

3. Expected audience

PhD students in digital heritage, archaeologists, researchers.

4. Hardware requirements

Participants are expected to bring their own laptop to manage large point clouds and run some classification processes in Colab. Laptop should have Intel core i5/i7 or AMD Ryzen 5/7 CPU with dedicated GPU >= 4GB VRAM, 16 GB RAM.

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