Final dissertation of the Master of Science in Geomatics (A.Y. 2023/2024)

April, 11 2025

Dr. Elena Andreini

Design and development of a monitoring protocol for habitats of Community interest in the Italian National Parks using mobile laser scanners

Internship at Bluebiloba Startup innovativa s.r.l.

This paper describes the design and development of a monitoring protocol for habitats of Community interest in the Italian national parks using portable terrestrial laser scanners (MLS – Mobile Laser Scanner). This initiative is part of the National Recovery and Resilience Plan (PNRR), specifically Measure M2C4 Inv. 3.2 "Digitalization of national parks and marine protected areas (DigitAP)," coordinated by the Institute for Environmental Protection and Research (ISPRA). The main objective is to collect high-resolution data to monitor habitat evolution and the pressures acting upon them. After a preliminary phase, during which the managers of each national park selected the sites to be monitored, data collection began through repeated surveys on representative sample areas. The project includes three surveys for each sample area, approximately six months apart: the first is currently underway, the second will take place in summer 2025, and the third in the following autumn-winter period.
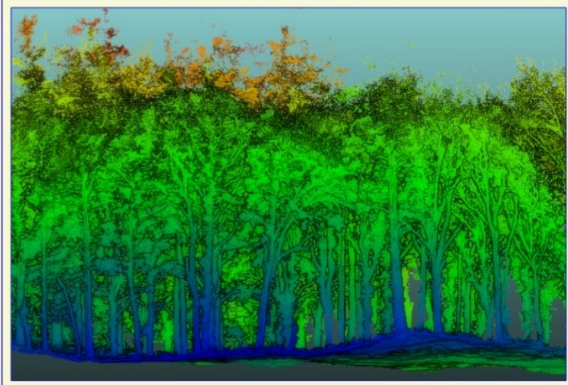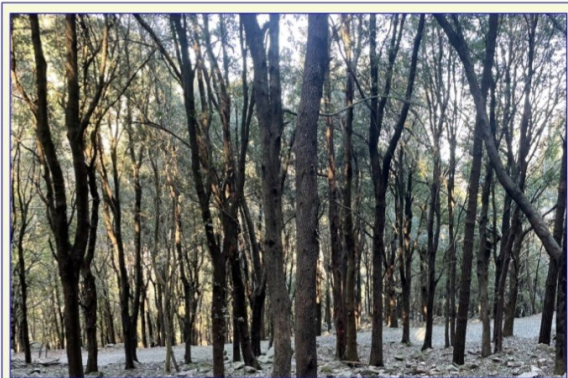
My internship at Bluebiloba Startup Innovativa S.r.l. focused on drafting the operational protocol and processing the first resulting point clouds. During the initial surveys, an evaluation of different MLS devices was conducted: GeoSLAM ZEB Horizon RT, Leica BLK2GO and XGRIDS Lixel L2 Pro. This assessment highlighted both their limitations and potential. The application of MLS for habitat monitoring presents advantages and challenges. Among its strengths is the ability to acquire detailed data to monitor structural vegetation changes, such as canopy growth or the effects of extreme weather events. However, certain issues arise, including the influence of weather conditions on survey quality and the difficulty of georeferencing point clouds in natural areas where GNSS coverage is weak or absent. In terms of precision, the tests indicate good consistency between consecutive surveys, although questions remain regarding the accuracy of the derived products. A test on a sample of trees compared traditional dendrometric surveys with estimates obtained from point clouds, yielding results consistent with the literature: comparisons showed

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that trunk diameter estimates were more accurate than tree height estimates. The future integration of MLS with drone-based surveys (ALS – Airborne Laser Scanner) could enhance data quality, especially for forest biomass estimation. In conclusion, the developed protocol represents a first step toward standardized and repeatable habitat monitoring in Italian national parks. Its application in the coming months will allow for an assessment of its effectiveness and potential improvements. Although the project's short duration does not permit the observation of significant physiognomic changes in vegetation communities, it will provide a solid methodological foundation for future monitoring activities and more informed management of natural resources in both protected areas and beyond.
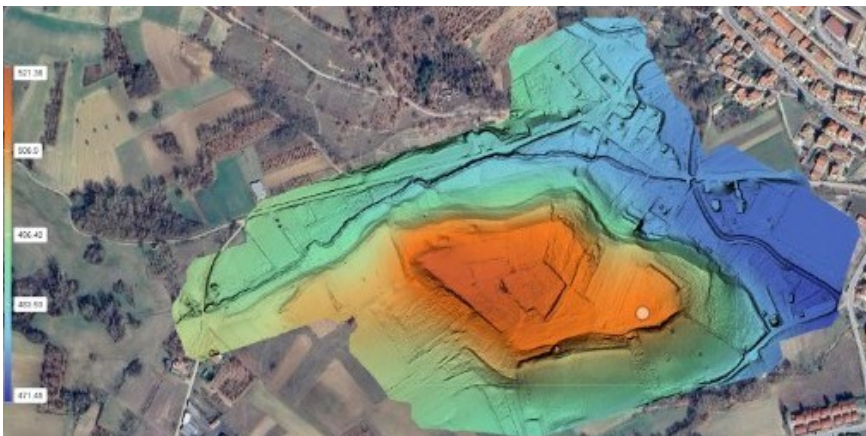
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Dr. Giacomo Baldi

LiDAR data analysis aimed to optimize segmentation and classification processes

Internship at Tecnostudi Ambiente Srl

This final thesis for the Second Level Master's Degree in Geomatics for the Academic Year 2023/2024 focuses on advanced LiDAR data analysis to optimize segmentation and classification processes, with particular attention to an archaeological area located in the central Apennines of Italy. The work was carried out at Tecnostudi Ambiente S.r.l. in Rome, aiming to improve the semi-automatic extraction and classification of LiDAR point clouds to identify sub-aerial structures of archaeological interest.

The equipment used includes DJI Matrice 350 drones equipped with LiDAR L2-RGB sensors and Global Mapper Pro software for data processing. The document provides a detailed description of LiDAR technology, highlighting its advantages and disadvantages compared to photogrammetry, and its main applications in sectors such as topographic surveying, archaeological research, forest management, and infrastructure inspection. The case study analyzes an archaeological area in the central Apennines, with the goal of optimizing classification parameters to obtain an accurate digital terrain model (DTM). The parametrization of the Global Mapper Pro software platform is described in detail, with particular attention to the settings and parameters used for LiDAR data classification, including terrain and vegetation classification. The application to the case study includes the evaluation of the minimum area for the terrain parameter and the comparison of longitudinal profiles to understand the quality of classification results. Additionally, a sensitivity analysis of the parameters was conducted, testing 20 different parametrization scenarios to determine the best values for terrain and vegetation classification. The conclusions of the work indicate that it is not possible to apply a single parametrization for all cases of morphology and soil cover. A specific parametrization is required for each study area, adapting the classification parameters to the specific characteristics of each area.

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Dr. Camilla Coccia

Application of Unmanned Surface Vessel (USV) in bathymetric surveys using Singlebeam and Multibeam echosounders

Internship at Microgeo Srl

To conduct bathymetric surveys echo sounders are employed—these instruments utilize sound waves to measure the bottom of bodies of water, such as a lake, reservoir, river, stream, canal, transitional waters or a stretch of coastal waters. To obtain accurate bathymetric data it is crucial to consider the range of factors that influence the measurements. Recent advancements in technology have introduced Unmanned Surface Vehicles (USVs), remote-controlled boats that can be equipped with various sensors depending on the nature of the survey.
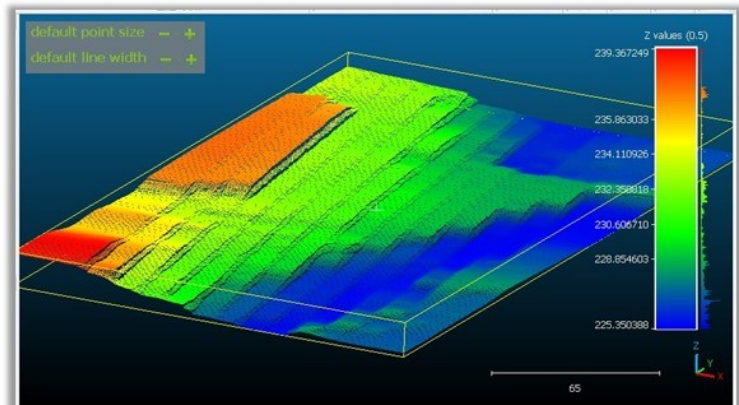
In this study, the USV Apache 4 was tested with both a single-beam echo sounder (D270) and a multi-beam echo sounder (HQ-400). The process involved data collection and subsequent post-processing to assess the performance, potential challenges, and overall reliability of this technology in meeting technical requirements.

Additionally, some processing was performed to evaluate how the data files generated by the survey software interacted with, and were compatible with, software used for goegraphic information management.

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Dr. Simone Lentini

A digital geological map of the Friuli-Venezia Giulia Region in the framework of the new "Digital Structural Model of Italy - scale 1:250.000"

Internship at Centro di GeoTecnologie dell'Università di Siena

The GIS (Geographic Information System) software, developed in order to meet the needs of a wide range of disciplines as in the case of geological cartography, allow for the computerization of thematic maps and the management of a large amounts of associated data into table form. The "Structural Model of Italy – scale 1: 500.000", covering the entire national territory, represents a unique product available in both analogical and digital formats, complete with a legend but without of both expalantory notes and an associated complete geological database.

The project relative to the new "Digital Structural Model of Italy – scale 1: 250.000" was born from the need to create a revised and complete product, by merging the most up-to-date small-scale cartography available for each region and suppliyng it with an integrated database, in a GIS environment.

In the latter framework, the "Geological Map of Friuli Venezia Giulia Region - scale 1: 150.000" is located. It represents the most recent overall product for the mentioned region and it is supplied with related "Explanatory Notes". These two materials make up the base for the current stage work.

The main purpose of the current project is aimed at producing a reworked digital map in a vector format of the geological thematic features of the Friuli-Venezia Giulia Region, to be associated with tables in which spatial data related to digitized geometries are organized by attribute fields.

The workflow is articulated into a series of steps, each of which follows various geological-cartographic analysis widely discussed in the accompanying report to the produced digital map, in order to obtain a series of consistent and well-orginized outputs:

- a georeferenced and rectified raster file from the original cartographic base, obtained by identifying a number of homologous control points with reference to a topographic basemap reprojected into the ETRS89-LAEA Europe coordinate system, together with the related table showing the error values of the control points themself;

- tables highlighting the subdivision of the features classes into their different fields, for both linear geometries (such as structural and stratigraphic elements) and point geometries (such as label-type features showing the characteristics of the geological polygons, derived from areas outlined by the intersecting linear features);

- tables highlighting the structure of the domains, corresponding to different lists of predefined values that any digitized geometric element from each feature class can assume for each attribute fields.

In the chapters concerning the cartographic and geological framework, as well as the analysis and the interpretation of the final results, a comparison with further recent geological and seismotectonic studies was carried out, to solve any discrepancies and improve the quality of the work.

Dr. Loris Lizzi

Integrated topographic survey techniques for riverbanks maintenance: an application on the Dendalo and Venna rivers (CH)

Internship at Studio Tecnico Associato Tecnoproject

The progressive and continuous development of computer science, and now especially flanked by the artificial intelligence, is providing Geomatics with new instruments and improved techniques for performing territorial surveys. The synergistic use of these different techniques and instruments allows for detailed and valuable results to be obtained, useful for a multitude of purposes. This work focused on utilizing integrated topographic surveying techniques (GNSS, LiDAR and aerial photogrammetry) to obtain water-level river cross-sections of the Dendalo and Venna rivers, in the province of Chieti, with the objective of supporting riverbanks maintenance.

During the survey phase, encompassing a working area of approximately 2 km², a mobile laser scanner and a UAV (Unmanned Aerial Vehicle) were employed. The subsequent combination of LiDAR data with data derived from the photogrammetric processing allowed to generate a 3D point cloud with a mean positional accuracy of about 5 cm. From this point cloud, a total of 100 cross-sections were extracted using the open source CloudCompare software, and these were ultimately organized into perspective views. These perspective views also helped to highlight critical aspects throughout the workflow, revealing that in the presence of dense riparian vegetation, both aerial and terrestrial LiDAR surveys are very efficient in defining riverbanks below vegetation, thereby suggesting that more should be invested in this effective geomatic technique.

Dr. Daniele Lucherini

Digital Twin of a Sewer Network
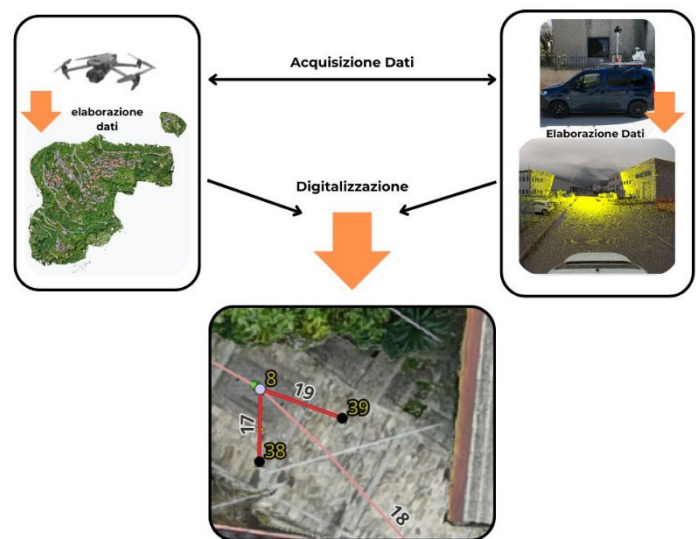
Internship at EAGLE Projects

In recent years, we have been witnessing a rapid technological evolution, and at the forefront of this evolution are the increasingly renowned Digital Twins.

Although modern SuperComputers, capable of handling ever more complex numerical models, attract attention, none of this would be possible without data acquired from the Real World and without these data being processed for profitable use by computers. The work carried out traces the entire Workflow that allows obtaining the files, in *.shp format, of the sewer network of Aurano (a municipality in Piedmont), at the request of Acqua Novara VCO S.p.A. These files will then be uploaded to the "WebGIS Acque di Lombardia" portal.

The Workflow includes the following phases:

a) Data acquisition 'in the field';
b) Post-processing of the acquired data;
c) Digitilization of the 'Real Twin.'

The files obtained in *.shp format, delivered to the client, use the WGS84/UTM zone 32N reference system (EPSG code: 32632).

In addition to its usefulness in terms of territorial administration, the product of the work carried out can be considered as the foundation from which it is possible to develop Predictive Models, in accordance with the latest concept of the Digital Twin.

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Dr. Federica Pallini

Monitoring of Altimetric Variations and Ground Settlement Using GNSS Surveys and UAV Photogrammetry: The Case of the Livorno Sedimentation Basins

Internship at Geocoste SNC

The thesis analyzes altimetric variations and ground settlement in the basin area of Livorno, where strategic infrastructure works are currently underway. The study focuses on the use of photogrammetric surveys with drones and Global Navigation Satellite System (GNSS) measurements.

The research has two main objectives: 1) to monitor altimetric variations due to the addition of external material, leading to the formation of a soil pyramid. This is achieved by generating and comparing Digital Terrain

Models (DTMs) derived from various surveys conducted on November 13, December 3, and December 27. Additionally, a volumetric analysis of smaller surrounding areas is performed to determine the amount of imported material; 2) to analyze ground settlement phenomena by measuring the elevations of settlement gauges installed in the area, particularly those positioned on and around the pyramid. In this regard, three GNSS surveys were conducted on December 17, January 14, and January 30. Furthermore, this analysis provides insights into the progress of the ongoing construction works.Data processing was carried out using the following software: Metashape, Global Mapper, Surfer 13, Convergo, and QGIS.

The analyses highlight an increase in the extension of the soil pyramid, with newly added sections raising the structure by approximately 5 meters, reaching a maximum height of around 9 meters. The amount of external material imported between November and December is estimated at approximately 32,245.81 m³. Additionally, the data indicate a progressive ground settlement, with an average altimetric reduction of a few centimeters. This research serves as a foundation for future studies, enabling the refinement of survey techniques and improving the planning of infrastructure interventions in the study area.
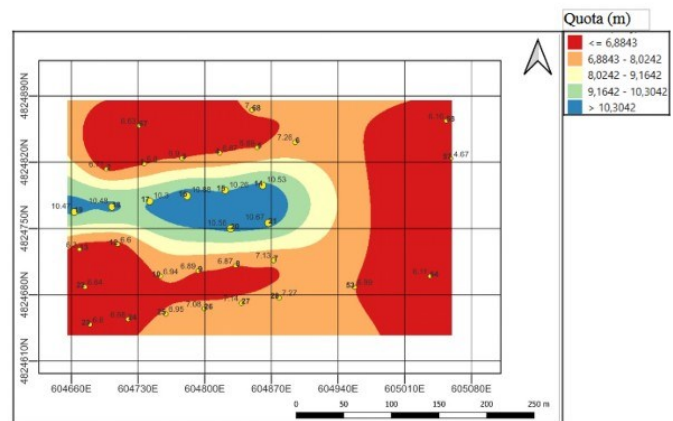
Dr. Paolo Salis

Surveying and 3D Modeling for the renovation of the Santa Chiara Monastery in Faenza

Internship at Monitor the planet

This study documents the three-dimensional survey of the Monastery of the Clarisse of Santa Chiara in Faenza, conducted using LiDAR technology and integrated with aerial photogrammetry and spherical images of the rooms. The main objective was to create an accurate database to support future requalification interventions following the transfer of the monastic community.

The survey, conducted in a local coordinate system, ensured precision and efficiency in data collection.

The final outputs include three-dimensional models, detailed floor plans and facade elevations, providing an essential reference for structural and design studies. This work highlights the benefits of integrating laser scanning and photogrammetry for the preservation of historical heritage and infrastructural management.

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Dott.ssa Rachele Salmaso

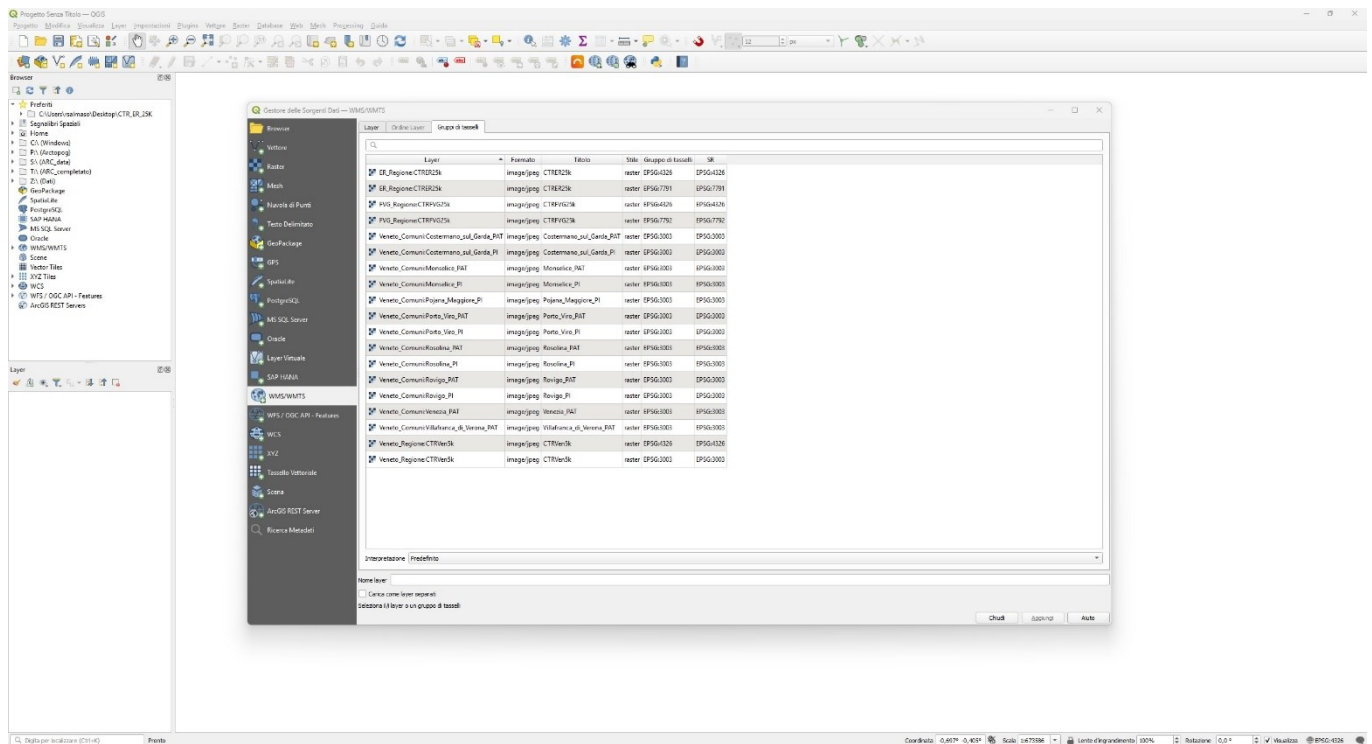*Creation of an internal storage system of national cartographic databases*

Internship at ARCSystem S.r.l.

This paper reports the project carried out during the internship period at Arcsystem, a Paduan company that deals with the design of network plants, territorial information systems and topographic services.

Specifically, the work was divided into several phases:

- research and elaboration of the cartographic databases of the regions of interest;

- publication and cataloging in an internal repository, also through a reworking in a GIS environment;

- study, management, parameterization and customization of the main support software, such as GeoServer and GeoNetwork;

- metadatation of the reprocessed layers, also through the use of QGis plug-ins.

The task aimed is the creation of an internal storage system of national cartographic databases, easily usable through a WMS consultation service.

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Dr.ssa Maria Valese

Spatial Multicriteria Analysis for Railway Track Design: Development of a Parametric GIS-based Tool

Internship at Centro di GeoTecnologie dell'Università di Siena

The planning of transport infrastructure is a critical component of sustainable development, closely linked to the environmental, socio-economic, and regulatory aspects of the territory. In this study, an approach based on Spatial MultiCriteria Decision Analysis (SMCDA) has been proposed to evaluate railway routes through the development of a parametric workflow integrated with GIS technologies. By leveraging GIS platforms, territorial optimization algorithms, and the harmonization of diverse datasets, the SMCDA methodology aims to provide optimal railway route solutions tailored to the specific objectives of case studies.

The selected case studies are the Rieti-Amatrice-Ascoli railway corridor and the Ragusa-Vizzini route.

The results highlight that combining ecological sustainability models with geological constraints enables the identification of optimal corridors, minimizing environmental impact and infrastructure costs. The implications of this study suggest a more structured integration of multicriteria methods into transport planning decision-making processes and a multi-scale approach that emphasizes the relationship between railway infrastructure—with all its morphological, constructive, and implementation implications—and the territory in terms of development potential and transformation dynamics.

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